A
SUPPLEMENT
TO THE
Philoſophia Britannica.

APPENDIX I.

CONTAINING

New Experiments in ELECTRICITY,

AND

The Method of making ARTIFICIAL
MAGNETS.

Illuſtrated with COPPER-PLATES.

K

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APPENDIX
To LECTURE I.

PART I.

Concerning the Improvements and new Experiments in ELECTRICITY.

THE Improvements in Electricity have been ſo great and numerous, that it would be almoſt in vain to attempt even the epitomizing of them all. We muſt therefore refer our inquiſitive Readers to the ſeveral Authors who have wrote on this Subject; but ſtill we think it neceſſary in a Treatiſe of this Kind, that there ſhould be a larger Account of this wonderful Power than what was given in the firſt Edition of this Work; and therefore we have added by Way of Appendix, two Papers of Experiments by Mr. CANTON, as we find them in the Tranſactions of the Royal Society. The firſt of which is contained in N° LIII. of Vol. XLVIII. Part I. The Title of which is,

Electrical Experiments, with an Attempt to account for their ſeveral Phænomena; together with ſome Obſervations on Thunder-Clouds, *by* John Canton, *M. A. and F. R. S.*

Experiment 1.

FROM the Cieling, or any convenient Part of a Room, let two Cord-balls, each about the Bigneſs of a ſmall Pea, be ſuſpended by Linen Threads of eight or nine Inches in Length, ſo as to be in contact with each other. Bring the excited glaſs Tube under the Balls, and they will be ſeparated by it, when held at the Diſtance of three or four Feet; let it be brought nearer, and they will ſtand farther apart; intirely withdraw it, and they will immediately come together. This Experiment may be made with very ſmall Braſs Balls hung by Silver Wire; and will ſucceed as well with Sealing-wax made electrical, as with Glaſs.

Experiment 2.

IF two Cork-Balls be ſuſpended by dry Silk Threads, the excited Tube muſt be brought within eighteen Inches before they will repel each other; which they will continue to do, for ſome time, after the Tube is taken away.

As the Balls in the firſt Experiment are not inſulated, they cannot properly be ſaid to be electrified: But when they hang within the Atmoſphere of the excited Tube, they may attract and condenſe the electrical Fluid round about them, and be ſeparated by the Repulſion of its Particles. It is conjectured alſo, that the Balls at this time contain leſs than their common Share of the electrical Fluid, on Account of the repelling Power of that which ſurrounds them; though ſome, perhaps, is continually entering and paſſing through the Threads. And if that be the Caſe, the Reaſon is plain, why the Balls hung by Silk, in the ſecond Experiment, muſt be in a much more denſe Part of the Atmoſphere of the Tube, before they will repel each other. At the Approach of an excited Stick of Wax to the Balls, in the firſt Experiment, the electrical Matter is ſuppoſed to come through the Threads into the Balls, and be condenſed there, in its Paſſage towards the Wax: for, according to Mr. *Franklin*, excited glaſs *emits* the electrical fluid, but excited Wax *receives* it.

Experiment 3.

LET a Tin Tube, of four or five Feet in Length, and about two Inches in Diameter, be inſulated by Silk; and from one End of it let the Cork-balls be ſuſpended by Linen Threads. Electrify it, by bringing the excited Glaſs Tube near the other End, ſo as that the Balls may ſtand an Inch and a half, or two Inches apart: Then, at the Approach of the excited Tube, they will by Degrees loſe their repelling Power, and come into Contact; and as the Tube is brought ſtill nearer, they will ſeparate again to as great a Diſtance as before: In the Return of the Tube they will approach each other till they touch, and then repel as at firſt. If the Tin Tube be electrified by Wax, or the Wire of a charged Phial, the Balls will be affected in the ſame Manner at the Approach of excited Wax, or the Wire of the Phial.

Experiment 4.

ELECTRIFY the Cork-balls as in the laſt Experiment by Glaſs; and at the Approach of an excited Stick of Wax their Repulſion will be increaſed. The Effect will be the ſame, if the excited Glaſs be brought towards them, when they have been electrified by Wax.

THE bringing the excited Glaſs to the End, or Edge of the Tin-Tube, in the third Experiment, is ſuppoſed to electrify it poſitively, or to add to the electrical Matter it before contained; and therefore ſome will be running off through the Balls, and they will repel each other. But at the Approach of excited Glaſs, which likewiſe *emits* the electrical Fluid, the Diſcharge of it from the Balls will be diminiſhed; or Part will be driven back, by a Force acting in a contrary Direction; and they will come nearer together. If the Tube be held at ſuch a Diſtance from the Balls, that the Exceſs of the Denſity of the Fluid round about them, above the common Quantity in Air, be equal to the Exceſs of the Denſity of that within them, above the common Quantity contained in Cork; their Repulſion will be quite deſtroyed. But if the Tube be brought nearer; the Fluid without, being more denſe than that within the Balls, it will be attracted by them, and they will recede from each other again.

WHEN the Apparatus has loſt Part of its natural Share of this Fluid, by the Approach of excited Wax to one End of it, or is electrified negatively; the electrical Fire is attracted and imbibed by the Balls to ſupply the Deficiency; and that more plentifully at the Approach of excited Glaſs, or a Body poſitively electrified, than before; whence the Diſtance between the Balls will be increaſed, as the Fluid ſurrounding them is augmented. And in general, whether by the Approach or Receſs of any Body; if the Difference between the Denſity of the internal and external Fluid be increaſed or diminiſhed; the Repulſion of the Balls will be increaſed, or diminiſhed accordingly.

Experiment 5.

WHEN the inſulated Tin Tube is not electrified, bring the excited Glaſs Tube towards the Middle of it, ſo as to be nearly at Right Angles with it, and the Balls at the End will repel each other; and the more ſo, as the excited Tube is brought nearer. When it has been held a few Seconds, at the Diſtance of about ſix Inches, withdraw it, and the Balls will Approach each other till they touch; and then ſeparating again, as the Tube is moved farther off, will continue to repel when it is taken quite away. And this Repulſion between the Balls will be increaſed by the Approach of excited Glaſs, but diminiſhed by excited Wax; juſt as if the Apparatus had been electrified by Wax, after the Manner deſcribed in the third Experiment.

Experiment 6.

INSULATE two Tin Tubes, diſtinguiſhed by *A* and *B*, ſo as to be in a Line with each other, and about half an Inch apart; and at the remote End of each, let a Pair of Cork Balls be ſuſpended. Towards the Middle of *A*, bring the excited Glaſs Tube; and holding it a ſhort time at the Diſtance of a few Inches, each Pair of Balls will be obſerved to ſeparate: Withdraw the Tube, and the Balls of *A* will come together, and then repel each other again; but thoſe of *B* will hardly be affected. By the Approach of the excited Glaſs Tube, held under the Balls of *A*, their Repulſion will be increaſed: But if the Tube be brought, in the ſame Manner, towards the Balls of *B*, their Repulſion will be diminiſhed.

In the fifth Experiment, the common Stock of electrical Matter in the Tin Tube, is ſuppoſed to be attenuated about the Middle, and to be condenſed at the Ends, by the repelling Power of the Atmoſphere of the excited Glaſs Tube, when held near it. And perhaps the Tin Tube may loſe ſome of its natural Quantity of the electrical Fluid, before it receives any from the Glaſs; as that Fluid will more readily run off from the Ends or Edges of it, than enter at the Middle: And accordingly, when the Glaſs Tube is withdrawn, and the Fluid is again equally diffuſed through the Apparatus, it is found to be electrified negatively: For excited Glaſs brought under the Balls will increaſe their Repulſion.

In the ſixth Experiment Part of the Fluid driven out of one Tin Tube enters the other; which is found to be electrified poſitively, by the decreaſing of the Repulſion of its Balls, at the Approach of excited Glaſs.

Experiment 7.

Let the Tin Tube, with a Pair of Balls at one End, be placed three Feet at leaſt from any Part of the Room, and the Air rendered very dry by Means of a Fire:

Electrify the Apparatus to a conſiderable Degree; then touch the Tin Tube with a Finger, or any other Conductor, and the Balls will, notwithſtanding, continue to repel each other; though not at ſo great a Diſtance as before.

THE Air ſurrounding the Apparatus to the Diſtance of two or three Feet, is ſuppoſed to contain more or leſs of the electrical Fire than its common Share, as the Tin Tube is electrified poſitively, or negatively; and when very dry, may not part with its Overplus, or have its Deficiency ſupplied ſo ſuddenly, as the Tin; but may continue to be electrified, after that has been touched for a conſiderable time.

Experiment 8.

HAVING made the Torricellian Vacuum about five Feet long, after the Manner deſcribed in the *Philoſophical Tranſactions*, Vol. xlvii. p. 370. if the excited Tube be brought within a ſmall Diſtance of it, a Light will be ſeen through more than half its Length: Which ſoon vaniſhes, if the Tube be not brought nearer; but will appear again, as that is moved farther off. This may be repeated ſeveral times, without exciting the Tube afreſh.

THIS Experiment may be conſidered as a Kind of ocular Demonſtration of the Truth of Mr. *Franklin*'s Hypotheſis; that when the electrical Fluid is condenſed on one Side of thin Glaſs, it will be repelled from the other, if it meets with no Reſiſtance. According to which, at the Approach of the excited Tube, the Fire is ſuppoſed to be repelled from the Inſide of the Glaſs ſurrounding the Vacuum, and to be carried off through the Columns of Mercury; but, as the Tube is withdrawn, the Fire is ſuppoſed to return.

Experiment 9.

LET an excited Stick of Wax, of two Feet and an half in Length, and about an Inch in Diameter, be held near its Middle. Excite the Glaſs Tube, and draw it over one half of it; then, turning it a little about its Axis, let the Tube be excited again, and drawn over the ſame half; and let this Operation be repeated ſeveral times: Then will that half deſtroy the repelling Power of Balls electrified by Glaſs, and the other half will increaſe it.

BY this Experiment it appears, that Wax alſo may be electrified poſitively and negatively. And it is probable, that all Bodies whatſoever may have the Quantity they contain of the electrical Fluid, increaſed, or diminiſhed. The Clouds, I have obſerved, by a great Number of Experiments, to be ſome in a poſitive, and others in a negative State of Electricity. For the Cork Balls, electrified by them, will ſometimes cloſe at the Approach of excited Glaſs; and at other Times be ſeparated to a greater Diſtance. And this Change I have known to happen five or ſix Times in leſs than half an Hour; the Balls coming together each Time, and remaining in Contact a few Seconds, before they repel each other again. It may likewiſe eaſily be diſcovered, by a charged Phial, whether the electrical Fire be drawn out of the Apparatus by a negative Cloud, or forced into it by a poſitive one: And by whichſoever it be electrified, ſhould that Cloud either part with its Overplus, or have its Deficiency ſupplied ſuddenly, the Apparatus will loſe its Electricity: Which is frequently obſerved to be the Caſe, immediately after a Flaſh of Lightning. Yet when the Air is very dry, the Apparatus will continue to be electrified for ten Minutes, or a Quarter of an Hour, after the Clouds have paſſed the Zenith; and ſometimes

times till they appear more than Half-way towards the Horizon. Rain, eſpecially when the Drops are large, generally brings down the electrical Fire: And Hail, in Summer, I believe never fails. When the Apparatus was laſt electrified, it was by the Fall of thawing Snow; which happened ſo lately, as on the 12th of November; that being the twenty-ſixth Day, and ſixty-firſt Time, it has been electrified, ſince it was firſt ſet up; which was about the Middle of May. And as *Fahrenheit*'s Thermometer was but ſeven Degrees above freezing, it is ſuppoſed the Winter will not entirely put a Stop to Obſervations of this Sort. At *London*, no more than two Thunder-Storms have happened during the whole Summer: And the Apparatus was ſometimes ſo ſtrongly electrified in one of them, that the Bells, which have been frequently rung by the Clouds, ſo loud as to be heard in every Room of the Houſe (the Doors being open), were ſilenced by the almoſt conſtant Stream of denſe electrical Fire, between each Bell and the Braſs Ball, which would not ſuffer it to ſtrike.

I SHALL conclude this Paper, already too long, with the following Queries:

1. MAY not Air, ſuddenly rarefied, give electrical Fire to, and Air ſuddenly condenſed, receive electrical Fire from, Clouds and Vapours paſſing through it?

2. Is not the *Aurora Borealis*, the Flaſhing of electrical Fire from poſitive, towards negative Clouds at a great Diſtance, thro' the upper Part of the Atmoſphere, where the Reſiſtance is leaſt?

As the ingenious Author of the foregoing Paper has given no Plate to illuſtrate thoſe Experiments with Figures; and as he has ſince contrived to ſhew them in a more neat and elegant Manner by Means of *Drinking-Glaſſes*, we ſhall therefore repreſent the Experiments this Way, as it may be eaſily practiſed by any private Perſon for his own Amuſement. Therefore, in *Fig*. 1. let A B and C D repreſent two Pieces of Wood about ſix or eight Inches long, half an Inch wide, and $\frac{1}{10}$ of an Inch thick; and at the End of each, let two fine Flaxen Threads be fixed, of about ſix Inches in Length, with two round Balls (about the Size of a white Pea, made of the Pith of Elder) be ſuſpended; then if the excited Tube be brought under the Balls at B, they will ſeparate, and repel each other, while the

Plate I. to this Appendix.

the Balls hanging from C D remain in Contact, placed at a Diſtance A C from the other; but if, while the Balls at B are electrified, the Glaſs be moved ſo that the Piece of Wood A B come in Contact with the Piece C D, then the Balls at B will loſe half the electric Fluid, which will be communicated to the Balls at D, and they will now repel each other; and the Diſtance between the Balls at B and D will be but half what it was at firſt between the two Balls at B. This Caſe is repreſented by the two Pieces of Wood at E F and G H.

THE Pieces of Wood at I K and L M repreſent the Caſe of the ſixth Experiment, where the Balls of L M are electrified negatively, and thoſe of I K poſitively.

THIS Method of ſupporting the Pieces of Wood with the Balls on Glaſſes, may be applied to a great Variety of curious Experiments, with regard to poſitive and negative Electrification, under all the different Circumſtances which have been mentioned in this Paper, and in thoſe that follow in the next by the ſame Author.

THE Torricellian *Vacuum*, mentioned in the eighth Experiment, is here repreſented in *Figure* the 2d, where *a c b* repreſents a hollow incurved Tube of Glaſs, whoſe Heigth *a c* is about three Feet. This Tube is firſt filled with pure Mercury, and then the Orifice of each Leg is inverted in two ſmall Baſons of Mercury *a b*. The Mercury in the Tube will ſubſide from the upper Part *c* to the equal Heigths *n o* in each Leg; then will there be a *Vacuum*, as in the common Barometer, in all the upper Part of the Tube. This Tube is then fixed in the Frame A B C D, either hapſed or tied on with Strings, as repreſented at *d g e f c*, which Frame is faſtened to the Side of the Room. If now, from the prime Conductor *i k*, a Wire or Flaxen String *h* carry the electric Matter to the Baſon *b*, it will run through the Quick-Silver into the vacuous Part of the Tube, and produce the ſurprizing Appearance of a Torrent of electrical Fire in the darkened Room, which will continue as long as the electrical Machine is in Motion.

THE 3d *Figure* repreſents a tall Glaſs Receiver, exhauſted by the Air-Pump; and a pointed Wire paſſing through a Cork in the Top conducts the electrical Fluid from the Machine to this *Vacuum*. The Machine being put in Motion, and the Room darkened, the Spectator will obſerve the

Electricity deſcending from the Point of the Iron, in the Appearance of a liquid Stream of Fire, of a pale whitiſh hue, like *Phoſphorus*, and of a thick Conſiſtence, like Cream; which plainly ſhew that the electrical Matter, as it is produced from common Bodies, is of a very different Nature from the Matter of common Light or Fire, as it hath a very different Colour, Smell, and Conſiſtence; and that it is not the pure Matter of Light, or indeed any Thing ſimilar to it, is evident from hence, that it has no different Refrangibility in its Rays, which is the well known Property of Light; and therefore upon the Whole we may conclude, that if Lightning, the *Aurora Borealis*, &c. be the Effects of Electricity, the Matter is ſtill ſupplied to the Clouds and the upper Regions of the Air from the Earth below, in the manner as Sir *Iſaac Newton* has taught in his Book of Optics, and which we have already taken Notice of in the firſt Part of this Lecture.

ANOTHER of Mr. Canton's Papers is contained in Number XCIII. Part II. of the ſame Vol. under the following Title:

A Letter

A Letter to the Right Honourable the Earl of Macclesfield, *Preſident of the Royal Society, concerning ſome new electrical Experiments, by* John Canton, *M. A. and F. R. S.*

My Lord,

AS Electricity, ſince the Diſcovery of it in the Clouds and Atmoſphere, is become an intereſting Subject to Mankind; your Lordſhip will not be diſpleaſed with any new Experiments or Obſervations that lead to a farther Acquaintance with its Nature and Properties.

THE reſinous and vitreous Electricity of Mr. Du Fay, which aroſe from his obſerving Bodies of the one Claſs to attract, what thoſe of the other would repel, when each were excited by Attrition, received no Light till the Publication of the ſecond Part of Mr. *Franklin's* Experiments; wherein it appears, that the one Kind of Bodies electrify poſitively, and the other negatively; that excited Glaſs throws out the electric Fire, and excited Sulphur drinks it in. But no Reaſon has yet been aſſigned, why vitreous Bodies ſhould receive, and reſinous Bodies part with this Fire, by rubbing them. Some Perſons indeed, of conſiderable Knowledge in theſe Matters, have ſuppoſed the Expanſion of Glaſs, when heated by Friction, to be the Cauſe of its receiving more of the electric Fluid than its natural Share; but this Suppoſition cannot be made with regard to Bodies of the other Sort, ſuch as Sulphur, Sealing-Wax, &c. which part with it when treated in the ſame Manner. The following Experiments, firſt made at the latter End of *December* 1753, and often repeated ſince, may perhaps caſt new Light on this difficult Subject.

HAVING rubbed a Glaſs Tube with a Piece of thin Sheet-lead and Flower of Emery mixt with Water, till its Tranſparency was entirely deſtroyed; after making it perfectly clean and dry, I excited it with new Flannel, and found it act in all Reſpects like excited Sulphur or Sealing-Wax. The electric Fire ſeems to iſſue from the Knuckle, or End of the Finger, and to ſpread itſelf on the Surface of this Tube, in the beautiful Manner repreſented at *A* and *B* in *Fig.* 1. Plate II.

IF this rough or unpoliſhed Tube be excited by a Piece of dry oiled Silk (eſpecially when rubbed over with a little Chalk or Whiting), it will act like a Glaſs Tube with its natural Poliſh. And in this Caſe, the Fire appears only at the Knuckle, or End of the Finger; where it is very much condenſed before it enters; as at *A* and *B* Plate II. in *Fig.* 2.

BUT if the rough Tube be greaſed all over with Tallow from a Candle, and as much as poſſible of it wiped off with a Napkin, then the oiled Silk will receive a Kind of Poliſh by rubbing it, and after a few Strokes, will make the Tube act in the ſame Manner as when excited at firſt by Flannel.

THE oiled Silk, when covered with Chalk or Whiting, will make the greaſed rough Tube act again like a poliſhed one: But if the Friction be continued till the Rubber is become very ſmooth, the electric Power will be changed to that of Sulphur, Sealing-Wax, *&c.*

THUS may the poſitive and negative Powers of Electricity be produced at Pleaſure, by altering the Surfaces of the Tube and Rubber; according as the one or other is moſt affected by the Friction between them: For if the Poliſh be taken off one Half of a Tube, the different Powers may be excited with the ſame Rubber at a ſingle Stroke. And the Rubber is found to move much eaſier over the rough, than over the poliſhed Part of it.

THAT poliſhed Glaſs electriſes poſitively, and rough Glaſs rubbed with Flannel negatively, ſeems plain, from the Appearance of the Light between the Knuckle, or End of the Finger, and the reſpective Tubes; but yet may be farther confirmed by obſerving, that a poliſhed Glaſs Tube, when excited by ſmooth oiled Silk, if the Hand be kept at leaſt three Inches from the Top of the Rubber, will at every Stroke appear to throw out a great Number of diverging Pencils of electric Fire, as Plate II. in *Fig.* 3; but not one was ever ſeen to accompany the rubbing of Sulphur, Sealing-Wax, *&c.* nor was I ever able to make any ſenſible Alteration in the Air of a Room, merely by the Friction of thoſe Bodies: Whereas the Glaſs Tube, when excited ſo as to emit Pencils, will, in a few Minutes, electrify the Air to ſuch a Degree, that (after the Tube is carried away) a Pair of Balls, about the Size of the ſmalleſt Peas, turned out of Cork, or the Pith of Elder, and hung to a Wire by Linen Threads of ſix Inches long, will repel each other to the Diſtance of an Inch and an Half, when held at Arm's-length in the

Middle of the Room. But their Repulſion will decreaſe as they are moved toward the Floor, Wainſcot, or any of the Furniture; and they will touch each other when brought within a ſmall Diſtance of any Conductor. Some Degree of this electric Power I have known to continue in the Air above an Hour after the Rubbing of the Tube, when the Weather has been very dry.

THE Electricity from the Clouds, in the open Air, may be diſcovered in the ſame Manner, if the Balls are held at a ſufficient Diſtance from Buildings, Trees, *&c.* as I have ſeveral Times experienced, by a Pair which I carry in a ſmall narrow Box with a ſliding Cover, (*Fig.* 4.) ſo contrived as to keep their Threads ſtraight, and that they may be properly ſuſpended, when let fall out of it: and theſe Balls determine whether the Electricity of the Clouds or Air be poſitive, by the Decreaſe; or negative, by the Increaſe of their Repulſion, at the Approach of excited Amber or Sealing-Wax. Plate I.

To electrify the Air, or Moiſture contained in it, negatively; I ſupport by Silk, between two Chairs placed Back to Back at the Diſtance of about three Feet, a Tin

Tube with a fine Sewing-needle at one End of it; and rub Sulphur, Sealing-Wax, or the rough Glaſs Tube, as near as I can to the other End, for three or four Minutes. Then will the Air be found to be negatively electrical; and will continue ſo a conſiderable Time after the Apparatus is removed into another Room.

THE Air without-doors I have ſometimes known to be electrical in clear Weather; but never at Night, except when there has appeared an *Aurora Borealis*, and then but to a ſmall Degree, which I have had ſeveral Opportunities of obſerving this Year. How far poſitive and negative Electricity in the Air, with a proper Quantity of Moiſture between, to ſerve as a Conductor, will account for this, and other Meteors ſometimes ſeen in a ſerene Sky, I ſhall leave to the Curious in this Part of Natural Philoſophy to determine. That dry Air at a great Diſtance from the Earth, if in an electric State, will continue ſo till it meets with a Conductor, ſeems probable from this Experiment: An excited Glaſs Tube with its natural Poliſh, being placed upright in the Middle of a Room, by putting one End of it in a Hole made for that Purpoſe in a Block of Wood, will generally loſe its Electricity in leſs than five Minutes, by attracting to it a ſufficient Quantity of Moiſture, to conduct the electric Fluid from all Parts of its Surface to the Floor. But if, immediately after it is excited, it be placed in the ſame Manner before a good Fire, at the Diſtance of about two Feet, where no Moiſture will adhere to its Surface, it will continue electrical a whole Day; and how much longer I know not. It may not be improper to mention here, that if a ſolid Cylinder of Glaſs be ſet before the Fire till quite dry, it may as eaſily be excited as a Glaſs Tube, and will act like one in every Reſpect: The firſt Stroke will make it ſtrongly Electrical.

IN a Paper I laid before the *Royal Society*, on the 6th of *December* laſt, I conjectured, that the Electricity of the Atmoſphere might be obſerved even in the Winter; which I have ſince found to be true: For in the ſucceeding Months of *January*, *February*, and *March*, my Apparatus was electrified no leſs than twenty-five Times, both poſitively and negatively, by Snow, as well as by Hail and Rain; and to almoſt as great a Degree when *Fahrenheit*'s Thermometer was between 28 and 34, as I ever knew it in the Summer, except in a Thunder-Storm.

I SHALL be glad, if theſe Obſervations and Experiments may engage Perſons of more Leiſure and ſuperior Abilities to purſue this Inquiry; as it is highly probable their Reſearches would be rewarded by many uſeful Diſcoveries. I have the Honour to be,

My Lord, &c.

PART II.

The Method of making ARTIFICIAL MAGNETS.

WE have already intimated, that Magnetiſm may be communicated by many different Ways to Bars of Iron, without the Touch or Uſe of real Magnetiſm; and this has been done in an extraordinary Manner by Mr. *Savory*, Mr. *Lovelace*, Dr. *Knight*, Mr. *Mitchell*, Mr. *Canton*, and others at home; alſo the Meſſrs. *Du Hamel* and *Antheaume* at *France*. But though the Methods taken by thoſe Gentlemen are different, yet the Force communicated to Steel Bars, properly tempered, is nearly the ſame in all; and the Method of ſucceeding beſt in theſe Caſes is generally deduced from a great Number of Experiments. For we are yet too little acquainted with Nature, and the Laws of Magnetiſm, to reaſon directly, or *a priori*, concerning its Properties; and as the ſtrongeſt artificial Magnets I have yet ſeen are thoſe made by Mr. *Canton*, I ſhall give his Paper directing the Method of making them, as it is contained in N° VI. Vol. XLVII. of the *Tranſactions*, under the following Title:

A Method of making artificial Magnets *without the Uſe of* natural *ones*; *communicated to the* Royal Society *by* John Canton, *M. A. and F. R. S.*

PRocure a Dozen Bars; ſix of ſoft Steel, each three Inches Long, one Quarter of an Inch broad, and one-twentieth of an Inch thick, with two Pieces of Iron, each Half the Length of one of the Bars, but of the ſame Breadth and Thickneſs; and ſix of hard Steel, each five Inches and an Half long, Half an Inch broad, and three-twentieths of an Inch thick, with two Pieces of Iron of half the Length, but the whole Breadth and Thickneſs of one of the hard Bars: And let all the Bars be marked with a Line quite round them at one End.

THEN take an Iron Poker and Tongs * Plate II. (*Fig.* 1.) the larger they are, and the longer they have been uſed, the better; and fixing the Poker upright between the Knees, hold to it near the Top one of the ſoft Bars, having its marked End downward, by a Piece of ſewing Silk, which muſt be pulled tight with the left Hand, that the Bar may not ſlide: Then graſping the Tongs with the right Hand a little below the Middle, and holding them nearly in a vertical Poſition, let the Bar be ſtroked by the lower End, from the Bottom to the Top, about ten Times on each Side, which will give it a magnetic Power ſufficient to lift a ſmall Key at the marked End: Which End, if the Bar was ſuſpended on a Point, would turn toward the North, and is therefore called the North Pole, and the unmarked End is, for the ſame Reaſon, called the South Pole of the Bar.

FOUR of the ſoft Bars being impregnated after this Manner, lay the other two (*Fig.* 2.) parallel to each other, at the Diſtance of about one-fourth of an Inch, between the two Pieces of Iron belonging to them, and a North and South Pole againſt each Piece of Iron: Then take two of the four Bars already made magnetical, and place them together, ſo as to make a double Bar in Thickneſs, the North Pole of one, even with the South Pole of the other; and the remaining two being put to theſe, one on each Side, ſo as to have two North and two South Poles together, ſeparate the North from the South Poles at one End by a large Pin, and place them perpendicularly with that End downward, on the Middle of one of the parallel Bars, the two North Poles towards its South, and the two South Poles towards its North End: Slide them backward and forward three or four Times the whole Length of the Bar, and removing them from the Middle of this, place them on the Middle of the other Bar, as before directed, and go over that in the ſame Manner; then turn both the Bars the other Side upward, and repeat the former Operation: This being done, take the two from between the Pieces of Iron, and placing the two outermoſt of the touching Bars in their Room, let the other two be the outermoſt of the four to touch theſe with: And this Proceſs being repeated till each Pair of Bars have been touched three or four Times over, which will give them a conſiderable magnetic Power, put the half dozen together after the Manner of the four (*Fig.* 3.) and touch with them two Pair of the hard Bars, placed between their Irons, at the Diſtance of about half an Inch from each other: Then lay the ſoft Bars aſide; and with the four hard ones let the other two be impregnated (*Fig.* 4.) holding the touching Bars apart at the lower End near two tenths of an Inch, to which Diſtance let them be ſeparated after they are ſet on the parallel Bar, and brought together again before they are taken off: This being obſerved, proceed according to the Method deſcribed above, till each Pair have been touched two or three Times over. But as this vertical Way of touching a Bar will not give it quite ſo much of the magnetic Virtue as it will receive, let each Pair be now touched once or twice over in their parallel Poſition between the Irons (*Fig.* 5.) with two of the Bars held horizontally, or nearly ſo, by drawing at the ſame Time the North of one from the Middle over the South End, and the South of the other from the Middle over the North End of a parallel Bar; then bringing them to the Middle again without touching the parallel Bar, give three or four of theſe horizontal Strokes to each Side. The horizontal Touch, after the vertical, will make the Bars as ſtrong as they can poſſibly be made: As appears by their not receiving any additional Strength, when the vertical Touch is given by a greater Number of Bars, and the horizontal by thoſe of a ſuperior magnetic Power. This whole Proceſs may be gone through in about half an Hour, and each of the larger Bars, if well-hardened *, may be made to lift twenty-eight Troy Ounces, and ſometimes more. And when theſe Bars are thus impregnated, they will give to an hard Bar of the ſame Size, its full Virtue in leſs than

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* Or two Bars of Iron.

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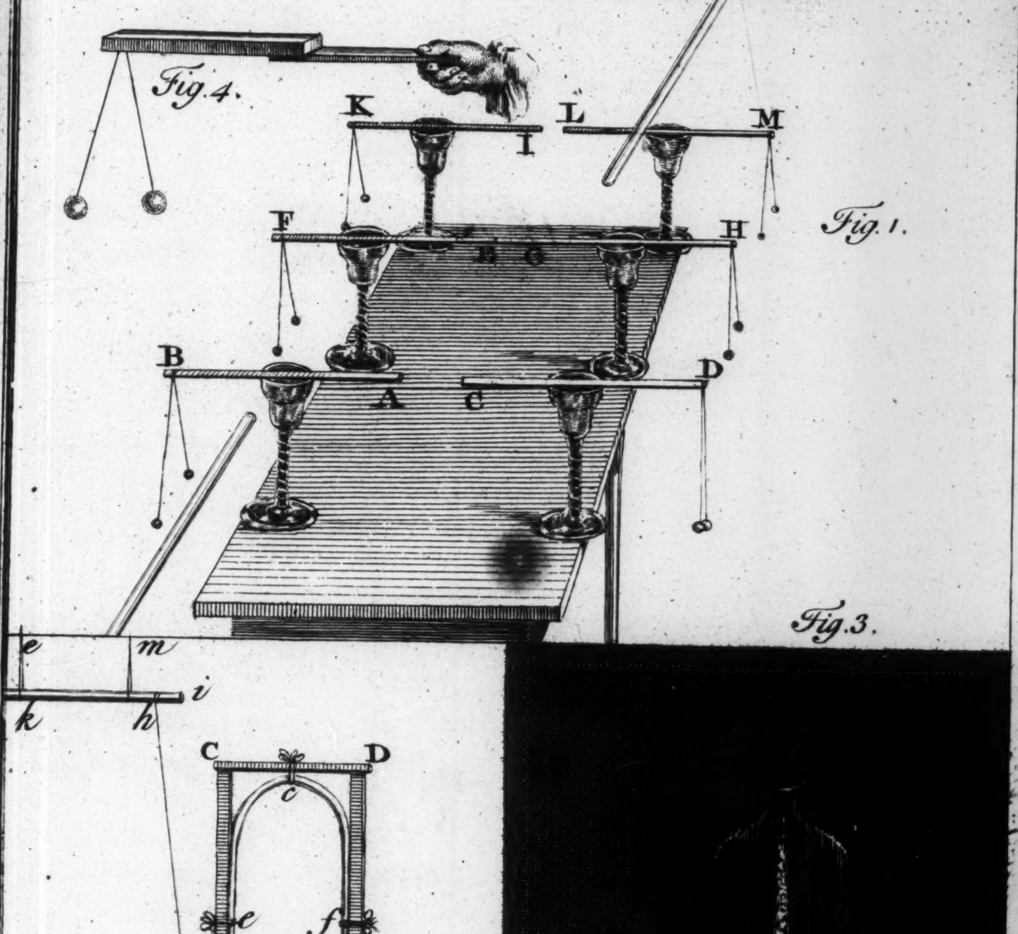
* The Smith's Manner of hardening Steel, whom I have chiefly employed, and whoſe Bars have conſtantly proved better than any I could meet with beſide, is as follows: Having cut a ſufficient Quantity of the Leather of old Shoes into very ſmall Pieces, he provides an Iron Pan, a little exceeding the Length of a Bar, wide enough to lay two Side by Side without touching each other or the Pan, and at leaſt an Inch deep. This Pan he nearly half-fills with the Bits of Leather, upon which he lays the two Bars, having faſtened to the End of each a ſmall Wire to take them out by: He then quite fills the Pan with the Leather, and places it on a gentle flat Fire, covering and ſurrounding it with Charcoal. The Pan being brought to ſomewhat more than a red heat, he keeps it ſo about half an Hour, and then ſuddenly quenches the Bars in a large Quantity of cold Water.

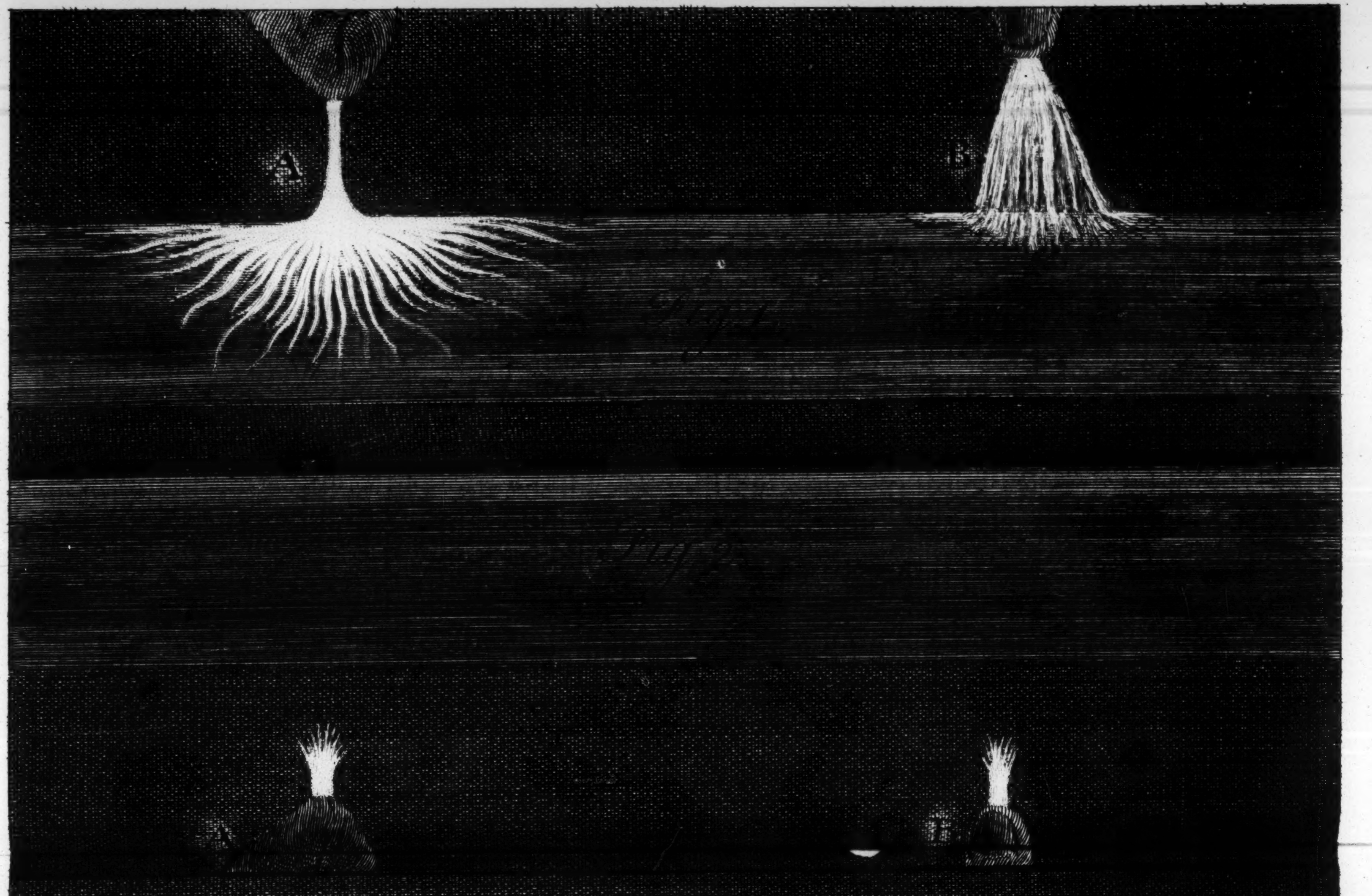
two Minutes: And therefore will anſwer all the Purpoſes of Magnetiſm in Navigation and experimental Philoſophy, much better than the Loadſtone, which is well known not to have ſufficient power to impregnate hard Bars. The half dozen being put into a Caſe (*Fig.* 6.) in ſuch a Manner, as that two Poles of the ſame Denomination may not be together, and their Irons with them as one Bar, they will retain the Virtue they have received: But if their Power ſhould, by making Experiments, be ever ſo far impaired, it may be reſtored without any foreign Aſſiſtance in few Minutes. And if, out of Curioſity, a much larger Set of Bars ſhould be required, theſe will communicate to them a ſufficient Power to proceed with, and they may in a ſhort Time, by the ſame Method, be brought to their full Strength.

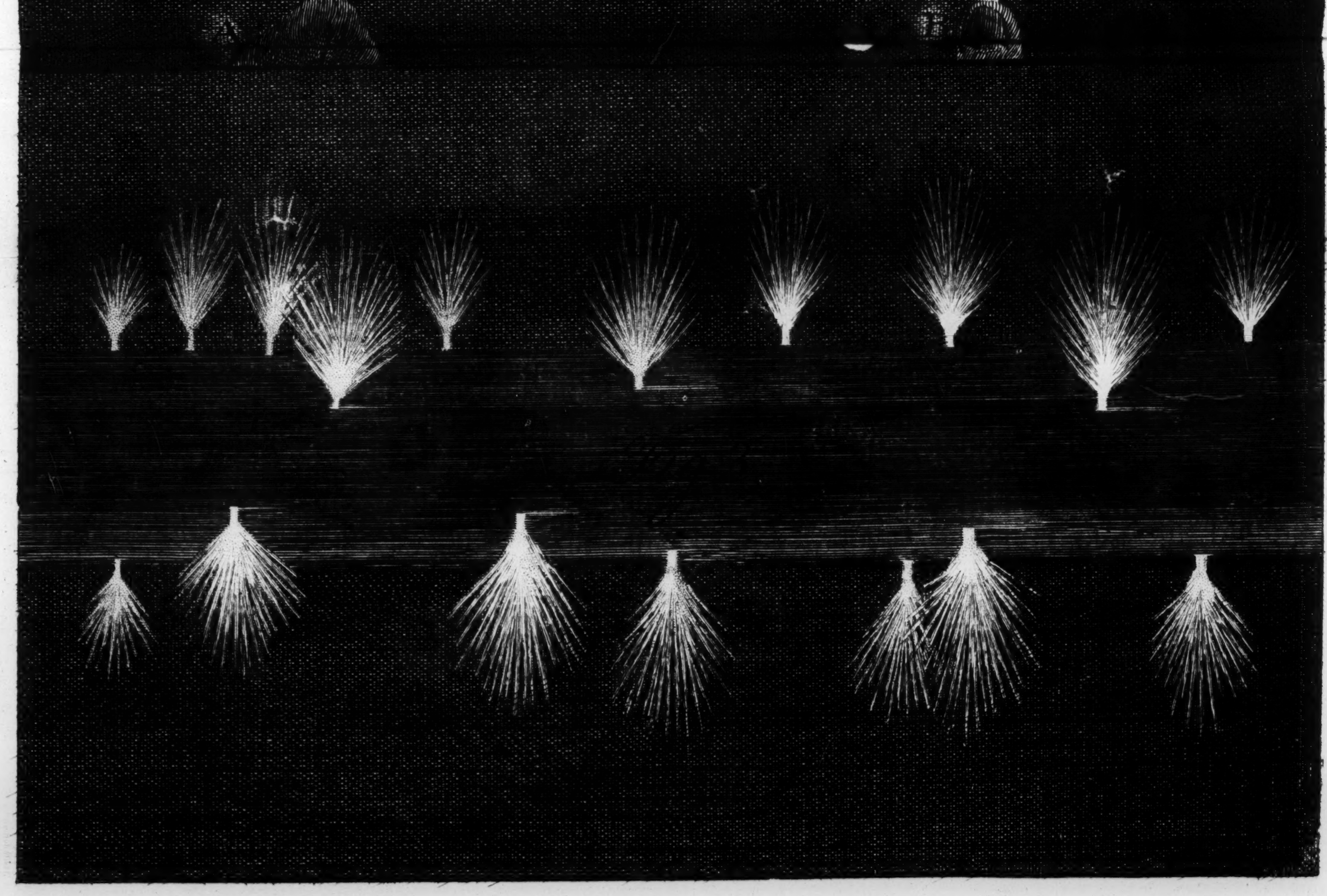
ELECTRICAL EXPERIMENTS.



Appendix I. *Plate* I.

ELECTRICAL EXPERIMENTS *in a* Darkend ROOM.





Appendix I. Plate II.

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ARTIFICIAL MAGNETS.

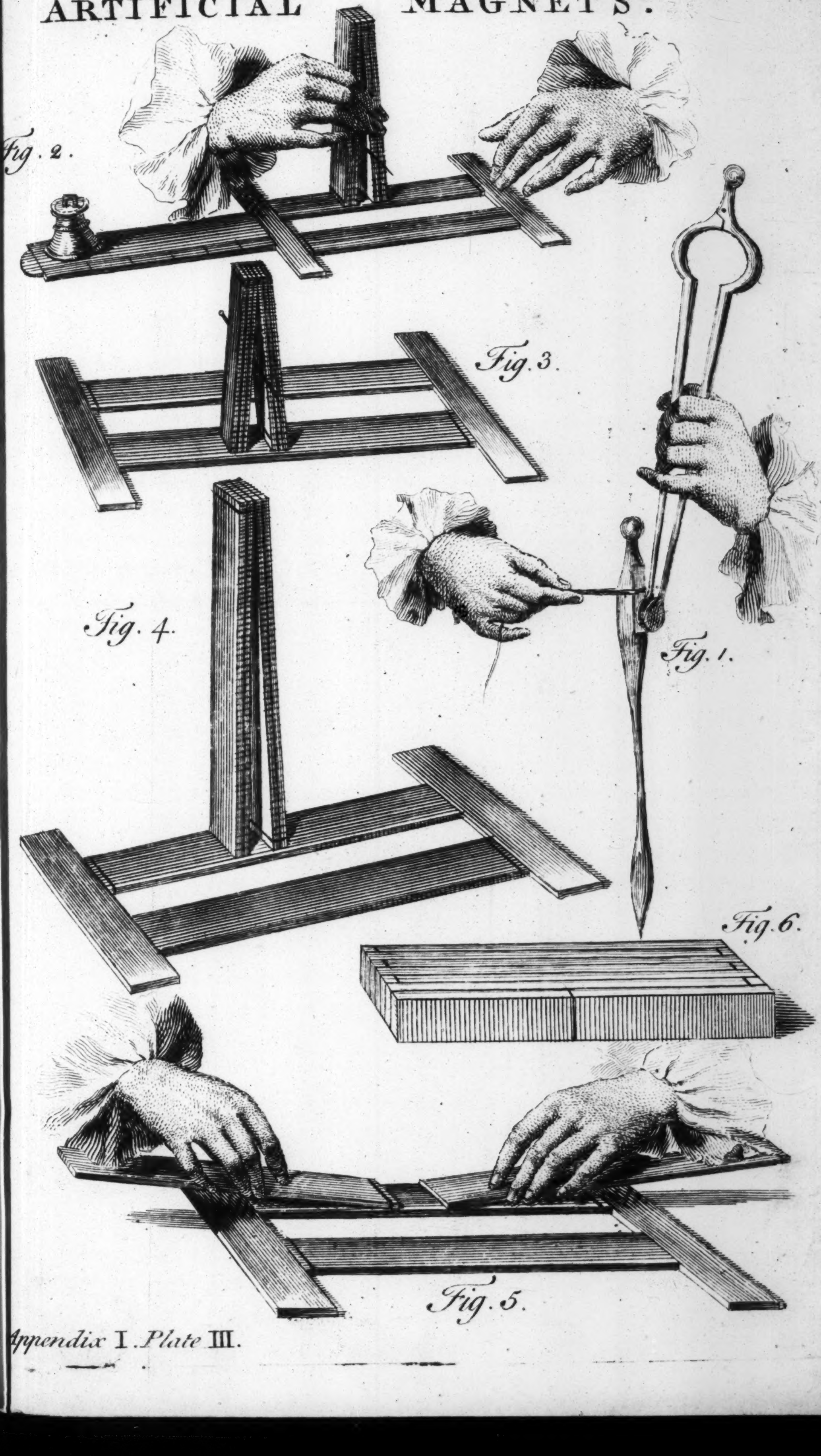
Fig. 2.
Fig. 3.
Fig. 4.
Fig. 1.
Fig. 6.
Fig. 5.

Appendix I. Plate III.

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APPENDIX II.

CONTAINING

I. A deſcription of a new Universal *Compound* Microscope.

II. The Deſcription of a new Solar Microscope.

III. The Deſcription of a new *Glaſs* Micrometer.

IV. New Improvements in Telescopes and Microscopes by a *Compoſition of Glaſſes.*

V. The Deſcription of a New Reflecting Telescope.

VI. Of Visual Glasses, or the Improvement of *Common Spectacles.*

VII. Deſcription of an Equatorial Telescope.

Illuſtrated with Copper-Plates.

By BENJAMIN MARTIN.

LONDON:
Printed in the Year MDCCLIX.

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APPENDIX II.

Concerning the IMPROVEMENTS *in* OPTICAL INSTRUMENTS.

I. *Of the* Univerſal Compound MICROSCOPE. II. *Of a new conſtructed* SOLAR MICROSCOPE. III. *A new* REFLECTING TELESCOPE *and Megalaſcope in one Inſtrument.* IV. *The Theory and Application of a* NEW MICROMETER, *by Means of a* divided Glaſs. V. *The* new Improvements *in refracting Teleſcopes conſidered.* VI. *Of the latter Improvements of* REFRACTING *and* REFLECTING TELESCOPES. VII. *The Nature and new Conſtruction of* VISUAL GLASSES *explained.* VIII. *A Deſcription of the* EQUATORIAL TELESCOPE.

I. *Of the* UNIVERSAL MICROSCOPE.

IN the firſt Edition of this Work a Plate of the univerſal Compound Microſcope was deſigned, but through Inadvertency was left out; and ſince that

Time having made conſiderable Improvements, both in its Form and Uſe, I have ſupplied that Deficiency, in the Print of one of the moſt elegant Conſtruction I can think of, and of the moſt extenſive Uſe; there being no ſmall Object of any Kind but what may be readily and eaſily viewed by it. It has all the Apparatus of Glaſſes, reflecting *Specula*, adjuſting Screws, *&c.* in common with others. Beſides which, the Contrivance of a moveable Stage for the Objects, and the Joint on the Top by which it is placed, either in a perpendicular or horizontal Poſition, are Advantages peculiar to this Conſtruction of a Microſcope. The Deſcription of which will be eaſy to underſtand as follows:

Plate I. A B C is the Body of the Microſcope.

A is the Magnifier, of which there are ſeveral of different Powers.

B is the large Middle-Glaſs for amplifying the Field of View.

C is the Eye-Glaſs at the Top.

D the Joint on which the Microſcope is moveable into a perpendicular, oblique, or horizontal Poſition at pleaſure.

E is a Screw, and F the Socket by which it is taken off and put on as Occaſion requires.

G H I is the moveable Stage on which Objects are placed to be viewed, and has a Motion about the Centre.

K is the Screw in the Centre L, by which that Motion is adjuſted and regulated.

M, N, are two Pieces of Braſs moveable upon a ſquare Stem, to adjuſt the Stage with its Objects to a proper Diſtance from the Magnifier A.

O is a Screw for fixing the Piece M to the Stem.

P the adjuſting Screw for moving the Part N up and down to its proper Situation.

Q R the Braſs Pillar on which the whole is ſupported.

S, T, V, three ſtrong Feet, ſerving as a firm Baſis to the Microſcope.

W a reflecting Mirror, moveable vertically in a Semicircle X, and horizontally in a Socket at Y.

THE Body of the Microſcope, the Stage, and the reflecting Mirror are taken off from the Stem, and the Legs folded together, ſo as to be conveniently placed, and take up but little Room in a Shagreen Caſe, which is therefore of a portable Size.

II. *Of the New* SOLAR MICROSCOPE.

THE Plate of the Solar Microſcope given in the firſt Edition being imperfect on two Accounts, *viz.* That it exhibited a View only of Part of the Inſtrument, and that of a very bad Conſtruction, I have thought it proper here to add the Figure of this extraordinary Inſtrument, with all the Improvements I have hitherto been able to make in it, which are as follow:

FIRST, The Common Solar Microſcope was made of *Wilſon's*, fixed to a proper Apparatus: But as this Form admitted only one Magnifier in the Inſtrument at a Time, it is changed for another, in which all the Magnifiers are contained in a Slider; and ſo all the different Degrees of magnifying an Object in a dark Room are immediately at Hand.

SECONDLY, With *Wilſon's* Part the Object was moved towards the Glaſs with a Screw; in this the Glaſs is moved towards the Object by Teeth and Pinion, which is found to be much the better Way.

THIRDLY, In the old Form the whole Body of *Wilſon's* Microſcope was obliged to be turned round ſeveral Times in getting a true focal Diſtance, by which Means a Motion of the large confuſed Image became ſo great as to be very diſagreeable to the Spectators, which is intirely prevented in this new Form, where there is only a Motion of the Object backward and forward in a right Line.

FOURTHLY, Thoſe which were made in Wood, had the Looking-Glaſs to move by Wheel and Pulley, with Cat-gut Strings ſtrained tight upon them. But this Mechaniſm being often at Fault, and giving Gentlemen a great deal of Trouble, I have ſubſtituted in this new Form a Wheel and Pinion with Teeth, as well in thoſe made of Wood as Braſs, by which the Motion of the Glaſs is rendered always conſtant, certain, and eaſy.

FIFTHLY, The Looking-Glaſs in the old Form is raiſed and depreſſed by a ſliding Wire; but in this new one, whether in Braſs or Wood, the ſaid Glaſs is moved by a Screw, and therefore will always ſtand in the Poſition it is ſet, and give no Trouble in the Experiment.

SIXTHLY, The illuminating Glaſs was ſcrewed on the Outſide of the Frame of this Inſtrument; but in this new Conſtruction it is placed within the End of the large Tube, which is much more convenient.

UPON the Whole, the *old Conſtruction* of the Solar Microſcope rendered it a heavy, clumſey, and ill-contrived Inſtrument; whereas every one who has ſeen the Form which I have here given in the Plate allow it to be the moſt neat and eaſy, light and uſeful that can be contrived. The ſeveral Parts of which are as follow:

Plate II. A B C D is the Square Plate ſcrewed on to the Window-Shutter.

E F is the Looking-Glaſs on the Outſide.

G H is the Screw or Wire by which the ſaid Glaſs is moved up and down by the Piece of Braſs

I K, moveable at each End for that Purpoſe.

L is the Pinion by which the Wheel contain'd under the Piece

M N is moved, and by which the Looking-Glaſs E F has a circular Motion given it.

O P is the Tube containing the Illuminating Glaſs at O, and a Drawer at P, by which a due Quantity of Light is thrown upon the Object.

Q R is

Q R is a Part ſubſtituted inſtead of *Wilſon*'s Microſcope, the Inner Part of which is fixed, and the outer Part moveable for the adjuſting a due focal Diſtance of the Object from the Glaſs.

R is the Part conſiſting of three Braſs Plates, in which the Sliders and Tubes containing the Objects are placed, as in *Wilſon*'s Microſcope, and kept together by a ſpiral Spring Wire within.

S is the Braſs Slider containing the ſeveral magnifying Glaſſes, which may be ſucceſſively applied to the Object by which it may be inſtantly magnified to any Degree at Pleaſure.

T is the Pinion by which the external Part Q V is moveable backward and forward, for procuring a true focal Diſtance, and conſequently the Image of the Object with the utmoſt Facility and Exactneſs.

III. *Of a New* REFLECTING TELESCOPE.

Plate IV. Fig. 1.

HAVING long obſerved the great Perfection and Uſefulneſs of Reflecting Teleſcopes above Refractors, ariſing from their Nature and Conſtruction, I have been more ſolicitous to cultivate and improve that Inſtrument than any other; eſpecially when I ſaw much Room left for that Purpoſe. The Reflecting Teleſcope, as uſually made, has not half the Uſes it is capable of; for when it is well conſidered, it will be found to anſwer the Purpoſes, not of a TELESCOPE only for viewing diſtant Bodies, but likewiſe it is the moſt compleat MEGALASCOPE, or Inſtrument for ſhewing all Objects at a very near Diſtance, and all the larger Sort of ſmall Objects in the greateſt Perfection. In the third Place, it gives the moſt perfect View of any ſmall Object, opake or tranſparent; and therefore is a MICROSCOPE of the very beſt Kind, as far exceeding common Refracting Microſcopes, as Viſion by reflected Light is more exquiſite and perfect than that by Refraction. Indeed there are two different Ways by which the Reflecting Teleſcope may be uſed as a Microſcope, each of which has its peculiar Advantage. In the fourth and laſt Place, this Inſtrument is a SOLAR MICROSCOPE, by being ſcrewed into the Plate A B C D of that Inſtrument above deſcribed. In all theſe ſeveral Ways I have uſed this Inſtrument with great Succeſs and

Pleaſure. I have, for theſe Purpoſes, contrived it in a different Form from that in which they are uſually made, and by which Means they are eaſily applicable to the foregoing Purpoſes; and even thoſe that will ſhew *Jupiter's* Moons are hereby rendered portable, or adapted to the Pocket.

THESE Pocket Reflecting Teleſcopes have a Drawer, in the End of which the ſmall Speculum is fixed, and adjuſted by Teeth and Pinion. They are equally applicable to uſe at Sea as at Land; and, notwithſtanding many People have been perſuaded, that Refracting Teleſcopes are moſt Uſeful at Sea, the Abſurdity of this Notion will evidently appear to any one who conſiders what we have in the foregoing Lecture ſufficiently demonſtrated, *viz.* That the natural Cauſe of indiſtinct Viſion is vaſtly leſs in a Reflecting Teleſcope than in a Refractor; and this upon the Suppoſition that the Quantity of Light and magnifying Power are the ſame in both. To conclude, I am thoroughly ſatisfied that if the Nature of this Inſtrument was well conſidered and underſtood, and People could be made ready at the Uſe of it, they who could afford to purchaſe it, would never have any other. But though the practical Application be very eaſy, yet as it is new and unuſual, and requires ſome ſmall Degree of Dexterity, I have no great Expectation of its being ſoon made public or brought into common Uſe, when I find by Experience how eaſy, cheap, and common every Thing muſt be for that Purpoſe, and how few there are to encourage any Thing of a different Kind in the preſent Age. I had thoughts of illuſtrating the particular Uſes of this *general Catoptric Inſtrument*; as likewiſe to ſhew how a *Reflecting Teleſcope*, a *Reflecting Microſcope*, and a *Reflecting Solar Microſcope*, by metalline Speculums of a different Form and Poſition, and of a more perfect Nature, might be conſtructed and applied to Uſe, but have declined that alſo for the Reaſons above mentioned.

IV. *The Theory of a* NEW MICROMETER.

AS the Perfection of Aſtronomy depends upon the moſt accurate Methods for meaſuring the Diameters of the celeſtial Bodies by Means of thoſe Inſtruments we call MICROMETERS, applied in Teleſcopes for that Purpoſe, it has given the ſagacious Aſtronomers Occaſion to contrive them in many different Forms; but all of them, till very lately, were applied in the Focus of the Object-Glaſs, to meaſure the Images of the heavenly Bodies formed there; and they may be juſtly reckoned among the moſt exquiſite Inventions of modern Mechanics.

BUT as the Diameter of the Sun and Moon are ſo much larger than the Planets, the Micrometer which ſerves for one, could not be ſo well adapted to meaſure the other; which put ſome Philoſophers upon thinking of a method by which they might meaſure the apparent Diameter of the Sun, without being obliged to take the Whole of the Sun's Diſk into the Teleſcope; and this they at length ingeniouſly contrived by forming a Teleſcope in ſuch a Manner as to make two Images of the Sun in the Focus of the Teleſcope at the ſame Time, and bringing them into Contact with each other. And this Inſtrument they properly call a HELIOMETER.

THE firſt Inſtrument of this Kind is of a late Date, and was the Contrivance of the late celebrated *Servington Savory*, Eſq; of *Exeter*, who, in the Year 1743, in a Letter to Mr. *George Graham*, dated *November* 30th, gives an Account of a new

Way

Way of meaſuring the Difference between the apparent Diameter of the Sun at the Time when the Earth is neareſt to and fartheſt from the Sun, with a Micrometer placed in the Teleſcope invented for that Purpoſe. Though the Charge, or magnifying Power of the Teleſcope is ſo great, that the Whole Sun's Diameter does not appear therein at one View.—" This, ſays " Mr. *Savory*, I doubt not, will at firſt " Sight ſeem impoſſible, ſince only a Part " of the Diameter appears, and no viſible " Mark or Point therein from which ſuch " Meaſure can be taken. And, indeed, it " is ſo by Obſervation with our common " Teleſcopes, whether refracting or reflecting ones. I have therefore contrived " ſome Dioptric Teleſcopes, and a reflecting one; either of which, by repreſenting the Object double, will, if well made, " anſwer the Deſign."

AFTER this he proceeds to ſhew at large, by cutting of a large Object-Lens into four Parts or Segments, and combining the two outer ones together, or the two Middle ones inverted, how he could form this double Image of the Sun; but as thoſe Images were not well defined and free from Colours, he proceeded to a third Method of forming thoſe Images by Means of two

Object-Lenſes entire, but of ſmall Diameter; but in this Caſe the Difficulty lay in getting Object-Glaſſes exactly centered, and of the ſame focal Length in ſo ſmall a Size.

He then had Recourſe to reflecting Mirrors, cut them aſunder, and combined their Fruſtrums to anſwer the ſame Purpoſe. However, all his Attempts of this Kind left the Inſtrument but imperfect; and after this we find the ſame Thing attempted that M. *Bouguer* read before the Royal Academy of Sciences at *Paris*, in the Year 1748, a *Memoir*, in which he deſcribes an Heliometer with two Object-Glaſſes for meaſuring the Diameter of the Sun and Planets. It is probable this was taken from Mr. *Savory*'s Experiments ſome Years before, but of this we have no particular Account.

However, it was ſoon conſidered, that an Object-Glaſs divided into two Segments through the Centre or Pole, would more conveniently anſwer the Purpoſe in thoſe two Parts, than could be done by two whole Glaſſes: Foraſmuch as each Segment would form an equal Image of the Sun, and at an equal Diſtance from the End of the Teleſcope; or in other Words, the focal Diſtance of each Segment would be exactly the ſame, and the Images of the Sun and Planets formed exactly in the ſame Plane in the Focus of the Teleſcope.

AND ſince the Centres of the Sun, each Segment of the Glaſs, and its Image are all found in one right Line, therefore if one Segment of the Glaſs be fixed in the End of the Teleſcope, the Image formed in it will alſo be fixed, or remain conſtantly in the ſame Part of the Focus; and if the other Segment be moved in the ſame Plane over it, as its Centre or Middle Point is removed from that of the fixed Segment, ſo likewiſe is the Centre of the moveable Image equally removed from the Centre of the fixed one; or the Centres of the two Images will always be equidiſtant with the Centres of the two Object-Glaſſes, and conſequently the Diameter of the Sun or Planet (being equal to its two Semidiameters) muſt be equal to the Diſtance between the two Centres of the Segments, when thoſe two Images are in Contact or touch each other in the Focus of the Teleſcope. And this is the whole Ground or Reaſon of the new Micrometer, which will be beſt illuſtrated by Figures, as it is applied to the Refracting or Reflecting Teleſcope, as follows:

LET A B C D repreſent any very diſtant Object, as the Sun, *&c.* and A B its Diameter; alſo let E F G S repreſent the Object-Glaſs conſiſting of two Segments E F G and E S G divided through the Centre N in the right Line E G. The Angle under which it appears at the End of the Teleſcope will be A N B equal to the Angle K N L, under which the Image K L is contained. Now, ſuppoſe the moveable Segment E F G were by a mechanical Contrivance drawn off to the Poſition H I, the Diſtance of their Centres would be N O; and the two Lines A N and B O paſſing through the Centres N, O, of the Segments, if produced, meet at the Focus in L; and ſince B L and B K do alſo paſs through the Centres N and O, and the Object being at an indefinitely great Diſtance, the Line O L will be parallel to N K, and conſequently the Angle N L O is equal to the Angle K N L or A N B, that is to ſay, *the Angle under which the Object appears from the End of the Teleſcope (or to the naked Eye) is equal to the Angle under which the Diſtance between the two Centres of the Segments appear from the Solar Focus of the Teleſcope.*

Plate III. Fig. 1.

AND this will be the Caſe in every Diſtance of an Object; for ſuppoſing the Object A B were at ſome near Diſtance from the Teleſcope, and ſubtended the ſame Angle A N B, the only Conſequence would be, that its Image would be formed at a greater Diſtance from the Glaſs; ſuppoſe at M P, it would ſtill be contained under the ſame Angle M N P, equal to N L O, as before, upon the Suppoſition that the Segment H I and B O produced meets A P in the Point P, that is to ſay, ſuppoſe that the Segment H I is in ſuch Poſition that the moveable Image Q R, formed by it, exactly coincides with the fixed Image M P, formed by the Segment E S G.

THIS likewiſe may be otherwiſe ſhewn from Theorem $\frac{dr}{d-r}=f$. (See *Annotat.* CXXV. *Art.* 27.) for putting A N $=d$, N P $=f$, and N L $=r$, or Focus of parallel Rays, we have $dr=fd-fr$; and thereby $d:f::d-r:r$. Conſequently $d+f:f::d:r$; that is, A Q : Q N :: A N : N L; and by ſimilar Triangles A Q B, N Q O, we have A Q : Q N :: A B : N O; therefore A N : N L :: A B : N O. Whence the Triangles A N B and N L O are ſimilar, and the Angle at N under which the Object appears is equal to that at L, under which the Diſtance N O of the Centres appears. *Q. E. D.*

CONCERNING this Vitreous Micrometer we may farther obſerve that its great Excellency conſiſts in this, that it depends ſolely in meaſuring the Diſtance of the Centres of the two Segments, not only when applied alone at the End of a Teleſcope, but even in Conjunction with the Object-Glaſs of any common Teleſcope; for, in *Figure* (2), let E G and H I repreſent the two Segments, as before, of a Glaſs whoſe focal Diſtance is very long, ſuppoſe, for Inſtance, 50 Feet, then at a ſmall Diſtance from it let A B repreſent the Object-Glaſs of a common long Teleſcope, whoſe focal Diſtance of parallel Rays is C *d*, or its Focus of very diſtant Object *d c.* Then this Glaſs, combined with the foregoing Segments, will have its Focus ſhortened, and the common Focus of both will be in Point *q*. Then becauſe the Triangles R O Q and P N M are ſimilar to the Triangles *r* O *q* and *p* N *m* reſpectively, therefore the Images R Q and P M will be ſimilar, and alike poſited to the two ſmall Images *r q* and *p q*; and therefore when theſe two Images are in Contact in the Focus of the Semi-

Plate III. Fig. 2.

Semi-Lenſes, they will likewiſe be in Contact in the ſhortened compound Focus. And as the Centres N and O of the two Semi-Lenſes G E and I H are ſeparated farther from, or brought nearer to each other, the Images in either Focus will be moved in ſimilar Manner; and when the Centres N and O coincide, the Images in each Focus reſpectively will alſo coincide, or become one entire Image, the Difference in every Caſe being only as to large and ſmall, greater or leſſer Diſtance. Conſequently in the Micrometer by which thoſe two Semi-Lenſes are moved by each other, the ſame Turns of the Screw which meaſures the Angle O P N, and which brings the Images into an exact Contact in the ſingle Focus at Q, will be neceſſary for the ſame Purpoſe in the compound Focus alſo; ſo that by this Means we have an Opportunity of meaſuring the ſaid Angle O P Q, without being obliged to have ſo great and ſo unmanageable a Length of the Teleſcope.

HOWEVER, the larger the focal Diſtance of the Lens A B is, the more diſtinct the Contact of the Images will appear; and becauſe this is the Point on which the whole Perfection of this Micrometer depends,

pends, it will be likewiſe neceſſary to have it ſo contrived, when applied to a Teleſcope, that the Centres N O may be equally diſtant from the Axis of the Teleſope or Centre of the Apparture on either Side; becauſe in this Caſe the Point of Contact in the two Images will be juſt in the Centre of the Focus, and therefore the moſt diſtinct that it poſſibly can be.

BUT the Application of this Micrometer to Refracting Teleſcopes will be leſs convenient than when it is applied to a Reflecting Teleſcope; for if it be placed on the open End of the Reflecting Teleſcope, as in *Fig.* 3, then will the Rays that tend to form the larger Images R Q and P M be incident upon the larger Speculum A B, and from thence reflected to a compound Focus, where the ſimilar Images *r q* and *p m* will be formed as before; the Rays proceeding from theſe two Images to the ſmaller Speculum a b, will be reflected back through the Hole of the larger, to form the Images *Q R* and *P M*, which likewiſe will ſtill be in Contact in the Focus of the Eye-Glaſs D C, where it will be diſtinctly perceived by the Eye at I. This Contact will likewiſe be ſhewn in the Middle of the Focus of the Eye-Glaſs, if the Centres Plate III. Fig. 3.

O and N are properly diſpoſed, as before mentioned.

FROM what has been ſaid, the general Rationale of this Micrometer will, I preſume, evidently appear; but one Thing muſt not paſs unregarded in an Affair of ſuch Moment and Conſequence as the meaſuring theſe ſmall Angles in the Science of Aſtronomy, which has been cuſtomary to ſuppoſe, that ſo far the Focus of a Lens, or the focal Diſtance of Rays parallel to its Axis, is equal to the Radius in a double and equally convex Lens. But this is too great an Error not to be noticed here; for in different Sorts of Glaſs there is found a different refractive Power, and the Focus of parallel Rays is at a different Diſtance in each; but this Diſtance in no Sort of Glaſs is equal to the Radius, but falls ſhort of it more or leſs. Now the foregoing Demonſtration regards the Radius, and not the focal Diſtance of parallel Rays. But this Affair will be beſt illuſtrated by Example as follows:

LET the Sine of Incidence be to the Sine of Refraction out of Air into Glaſs as m to n; and let $\frac{m-n}{n}=a$, then will a expreſs the refractive Power of the Glaſs;

and the Theorem for a double and equally convex Lens will be $\frac{dr}{2ad-r}=f$, which for parallel Rays, becomes $\frac{r}{2a}=f$; whence $r=2af$; or $f:r::1:2a$.

BY Experiments I find in *white Flint-Glaſs* $a=0{,}6$ nearly; in *Crown*, and *yellow Plate*, $a=0{,}532$; and in *white Plate*, $a=0{,}573$. In all Caſes therefore $2a$ exceeds Unity; and juſt in that Proportion will the Radius exceed the focal Diſtance of parallel Rays. Now ſuppoſing the Error leaſt of all, or the Micrometer to be made of *green or yellow Glaſs*, then $2n=1{,}064$; and $f:r::1:1{,}064$. Wherefore by taking the focal Diſtance inſtead of Radius, the Angle meaſured by the Micrometer will be larger than the real Angle in the Proportion of 1,064 to 1; or it will give 6 Seconds in every 100, more than there really is in meaſuring the Diameters of the Planets. Therefore the Radius, and not the Focus of parallel Rays is the Diſtance to be taken in meaſuring theſe ſmall Angles.

WITH regard to the Planets, as *Jupiter* is the largeſt of all, and ſubtends an Angle to the Eye of $3' 12''$, the Diameter of his Image in the Focus of a 50 Foot Glaſs will be about half an Inch, and that will be the utmoſt Diſtance to which the Centres of the Segments will be required to be ſeparated for meaſuring the apparent Diameters of the Planets.

BUT for a HELIOMETER, the Diameter of the Sun being near ten times as great as that of *Jupiter*, will require the Centres of the Segments in a Glaſs of 40 or 50 Feet Focus to be removed from each other at leaſt to the Diſtance of 4 or 5 Inches; and to take in the whole Syſtem of *Jupiter*'s Moons, the Diſtance of the Centres will be required much larger; and therefore for ſuch Purpoſes the Segments of Glaſſes of a leſs focal Length muſt be uſed.

As this Micrometer has many Advantages above that which is in common Uſe, ſo on the other Hand it is liable to ſome Objections; for ſince the Images of Objects can never be well defined but in the very large focal Diſtances, and ſince thoſe Glaſſes are not made true without great Care and Difficulty, they will come dear, and then we muſt run the Riſque of ſpoiling them in cutting them aſunder; for if they are not cut nicely through the Centre it will derogate from the Value and Goodneſs of the Inſtrument. Alſo ſince at the ſame Time a very great magnifying Power is required in the Inſtrument to which it is applied, it can be applicable for Aſtronomical Purpoſes in only Reflecting Teleſcopes, becauſe of the Conveniency of adapting it to the Tube of the Teleſcope, and moving it at the ſame time you are obſerving the Object thro' it.

V. *Concerning the Improvement of Refracting* MICROSCOPES *and* TELESCOPES *by a Compoſition of Glaſſes.*

IT has been already ſhewn in *Annotation* CXXVIII. *Art.* 18. *that the Errors ariſing from the different Refrangibility of the Rays of Light will be as the Cubes of the lineal Aperture of the Glaſs directly, and the Square of its Diſtance inverſely*; and conſequently in Glaſſes of the ſame Aperture the Indiſtinctneſs of Viſion will be inverſely as their focal Diſtances; wherefore if, while the magnifying Power and Aperture of the Lens continue the ſame, we can increaſe this Ratio of the focal Diſtance to the ſaid lineal Aperture, we ſhall in that Proportion increaſe the Diſtinctneſs of Viſion, which is the very Point in which the Perfection of Microſcopes and Teleſcopes conſiſt.

Plate IV. Fig. 2. To illuſtrate this, let A E D G be a Lens, F, the Focus of parallel Rays, f the Place of an Object O B; through the Point F draw a Line to interſect the Object in the Point B, and falling upon the Lens in the Point A. This Ray will be refracted into A M, parallel to the Axis of the Lens F C O; from f draw the Line F A, which by the Lens will be refracted to its reſpective Focus V; then will L V repreſent the Image of Part of the Object B f; let M N be an Eye-Glaſs by which that Image is to be viewed, which therefore muſt be placed at its focal Diſtance P V; from it draw P L, and parallel thereto draw M O, then will the Angle M O P be the viſual Angle under which the Image L V will appear to the Eye at O.

WE are now to ſhow how this Image may be viewed with more Diſtinctneſs, and under the ſame Angle and Aperture as before; and this is effected by ſubſtituting two Glaſſes H I and U S inſtead of the ſingle Glaſs M N; for by this Means we ſhall make the ſame Angle by two Refractions which before was made by one, and that will produce the deſired Effect;

for let the Glaſs H I be placed at its focal Diſtance I P from the Centre of the firſt Glaſs M N, then will the Ray A H (which before proceeded to M) be now refracted into H P, and the Ray A V will at K be refracted into K Z; draw the Line I L and it will interſect the Ray H P in X, and X Z will be the Image of the Object B f. All this we have demonſtrated in the Optical Lecture.

LET this Image be viewed by the Eye-Glaſs U S, whoſe focal Diſtance T Z or T P may be ſuch that the Ray H P may be now a ſecond Time refracted at U into U Q; parallel to M O or L P draw T X, which will alſo be parallel to U Q, then will the Image Z X, or rather the Part of the Object B f, be ſeen under the Angle T Q U equal to M O P, as at firſt.

Now it is evident, that were the Glaſs U S alone by itſelf, the Indiſtinctneſs of Viſion would be inverſely as T Q, for that would then be the focal Diſtance of the Glaſs; but now this Glaſs T U, in Compoſition with the other Lens H I, ſhews the ſame Image under the ſame Angle and Aperture with the focal Diſtance T P; the Indiſtinctneſs of Viſion therefore now will be inverſely as T P, or in other Words, the Diſtinctneſs of Viſion in the firſt Caſe by a ſingle Glaſs will be to the Diſtinctneſs of the Glaſſes in Compoſition as T Q to T P, or the Image will appear ſo much diſtincter by the two Glaſſes H I and U S together, than it would do by the ſingle Eye-Glaſs M N alone, in Proportion as T P is greater than T Q; all which is evident from the foregoing Principles of Optics.

WITH reſpect to the Lens A E D, if it be a ſmall one, and the focal Diſtance C F be ſhort, then will it repreſent the Object-Glaſs of a Microſcope, and the ſmall Object O B will be viewed to much greater Advantage by Means of the two Eye-Glaſſes H I and U S, than by a ſingle Eye-Glaſs alone M N. Whence the Reaſon is evident of the uſual Conſtruction of this Inſtrument, as we have before ſhewn.

BUT if A E D G be the Object-Glaſs of a Teleſcope, and F C its Focus, then will O B repreſent a diſtant Object, whoſe Image W L is that which is viewed by a ſingle Eye-Glaſs M N in what is called the *Aſtronomical Teleſcope*; but this Image is more diſtinctly viewed by two Glaſſes I and T, than by one alone; and therefore ſuch a Telea Teleſcope ſhould conſiſt at leaſt of three Glaſſes.

In the common Teleſcope the Image L W is conſidered as an Object, and another Image is formed of it, as was ſhewn in Figure 8, of Plate XLVIII. and as we have now ſhewn that each Image requires the Addition of a Lens to ſhew it more diſtinctly, inſtead of the three Eye-Glaſſes which you there ſee repreſented in a common Teleſcope, there ought to be the Addition of two more, or five in all, next the Eye, to ſhew the Object to the beſt Advantage. Theſe, together with the Object-Glaſs, make ſix Glaſſes in all, in Teleſcopes of the beſt Sort.

If A C D repreſent the ſmall Speculum of a Reflecting Teleſcope, then will O B be the Image formed by the large Speculum before it, and I, T, will be the two Glaſſes contained in the Eye-Piece of a Reflecting Teleſcope. And, indeed, with a little Reflection it will appear, that if two Glaſſes, by breaking the Refraction into two Parts, is an Advantage, three Glaſſes will be more ſo, and therefore in ſome Caſes might be ſucceſsfully applied.

Also ſince the Diſtinctneſs of Viſion is by a Compoſition of Glaſſes promoted, the Aperture of the Glaſs next the Eye may be ſomewhat encreaſed, and conſequently the Field of View thereby enlarged, which is the great Advantage of the Six-Glaſs Teleſcope.

We ſhall now give the analytical Inveſtigation of the focal Diſtance of the three Glaſſes; in order to which,

Let $F = IP$, the focal Diſtance of the Glaſs H I.
$y = TP$, the focal Diſtance of the Glaſs U S.
$x = PO$, the focal Diſtance of the Lens M N.

And becauſe the Image W L is to be conſidered as an Object with regard to the Glaſs H I, therefore put $IV = d$, and $IZ = f$, and we ſhall have $\frac{Fd}{F+d} = f$, (as we have ſhewn in *Annot.* CXXV.) and from hence we get $d = \frac{Ff}{F-f}$.

But becauſe of ſimilar Triangles I Z X, I V L, and I T X, I P L, we have $f : d :: IZ : IV :: ZX : VL :: IX : IL :: IT : IP :: f+y : d+x$; conſequently $f : d :: y : x$, Therefore $d = \frac{fx}{y} = \frac{Ff}{F-f}$. Hence we get $f = \frac{Fx - Fy}{x} = D - y$ (by putting $D = f + y = IT.$) Whence laſtly, $x = \frac{Fy}{F + y - D}$; $y = \frac{Fx - xD}{F - x}$; $F = \frac{xD - xy}{x - y}$; $D = F + y - \frac{Fy}{x}$.

By theſe Theorems we ſolve any Problem relating to the Compoſition of Glaſſes for any given Power of Magnifying; for Inſtance, ſuppoſe the focal Diſtance x of the Lens M N were $1\frac{1}{2}$ Inch, and that of the large Glaſs H I, *viz.* $F = 3$, to find the focal Diſtance y of the Lens U S that is to be combined with it at the Diſtance $D = 2$ Inches, that ſhall magnify juſt as much as the ſingle Lens MN. We have the Anſwer by the ſecond Theorem, where $x = 1{,}5$; $F = 3$, and $D = 2$; hence $y = \frac{3 \times 1{,}5 - 1{,}5 \times 2}{3 - 1{,}5} = \frac{4{,}5 - 3}{1{,}5} = 1$. So the focal Diſtance of the Lens U S muſt be one Inch. If $D = 1$, then $y = 2$; and if $D = 0$, then $Y = 3$.

Hence two Lenſes put together, whoſe focal Diſtances are equal, magnify in the ſame Degree with a ſingle Lens of half that focal Diſtance, at the ſame Time that the Refraction is made *at twice*, and conſequently the Error ariſing from thence but half ſo great as by the ſingle Glaſs, where the whole Refraction is made *at once*. For if F be the focal Diſtance of each of the two large ones, then the Error by Refraction at the firſt is as $\frac{1}{F^2}$, and it is the ſame the ſecond Time at the ſecond Glaſs. Whence the Error of both Refractions will be as $\frac{1}{F^2} + \frac{1}{F^2} = \frac{2}{F^2}$. Now let $x =$ focal Diſtance of the ſingle Glaſs, then the Error by Refraction through it will be as $\frac{1}{x^2}$. Therefore the Error by both Glaſſes will be to that of the ſingle one as $\frac{2}{F^2} : \frac{1}{x^2} :: x^2 : \frac{F^2}{2} :: 1 : 2$ (becauſe $x = \frac{1}{2}F$ by Suppoſition.)

Plate IV. Fig. 3. HENCE alſo it appears, that a *double and equally convex Lens* A B C D A will ſhew an Object L M placed in its Focus to twice the Advantage as a *Plano-Convex* Lens A E C A will do of the ſame focal Diſtance D F; ſince the double Convex may be conſidered as two ſingle Plano-Convexes A B C A and A D C A, whoſe focal Diſtances are each

equal to D G, and being placed with their plane Surfaces A C together, the Ray L A by two Refractions through them, falls upon the Centre F of the Circle D H G; agreeable to what we have ſhewn in the Theory. But if this Object L M is to be viewed by a Plano-Convex A E C A of the ſame focal Diſtance E F, then will the Radius of its Convexity be E K $= \frac{1}{2}$ D F; and therefore the Convexity will be twice as great as that of the *Double Convex*, and conſequently will produce twice the Error by Refraction of the Rays L A at once.

HENCE likewiſe the Reaſon is evident why we ſee an Object much better with the plane Side (of the Plano-Convex Lens) turned to the Eye, than when the Convex Side is placed next to it; for in the former Caſe the Refraction is made at twice, (*viz.* both at the convex and plain Surface) whereas in the latter Caſe, parallel Rays are refracted but once, and therefore the Error much greater.

VI. *Of the latter Improvement of* REFRACTING *and* REFLECTING TELESCOPES.

BESIDES the laſt mentioned Conſtruction of Teleſcopes, which is to be looked upon only as a Correction of dioptric Inſtruments, there is of late another Improvement ſtill greater, which tends not only to leſſen the Abberation of Rays in refracted Light, but even to prevent any ſenſible Effects ariſing therefrom; and this is done by Means of a *double* or *treple Object-Glaſs* in all thoſe Inſtruments where an Object is viewed by Means of its Image formed by refracted Light. The Conſtruction of a Teleſcope for this Purpoſe with two Object-Glaſſes in Fig. 4, where ABCD is a Plano Concave Lens of what is called *white Flint* Glaſs, and CDE a Double Convex Lens of *green* or *Crown* Glaſs; by Means of the different refractive Power of theſe two Sorts of Glaſs and their unequal Figures, it comes to paſs, that all the Rays of Light incident upon thoſe Glaſſes from diſtant radiant Objects, will paſs through them in ſuch a Manner, that whatever Abberation is occaſioned in the heterogeneal Rays in Refraction through the

Plate IV.

the firſt Glaſs is ſo far corrected by the ſecond, that thoſe Rays emerge from it nearly parallel among themſelves, and are converged to one Focus (F) forming an Image I M, not ſenſibly compounded or coloured, and therefore more perfect and diſtinct when viewed by the Eye-Glaſſes than that can be which is made by a ſingle Object-Glaſs.

Now, if thoſe two Glaſſes could abſolutely prevent the Abberation of Rays, or produce an Image entirely free from Confuſion and Colours, then only three Eye-Glaſſes would be neceſſary to view it, *viz.* E, G, H; for ſince, according to common Optics, the Lens H corrects the Errors ariſing from Refraction in the Lens E; and therefore if the Image I M be perfect, the ſecond Image K L will be ſo likewiſe, and therefore may be viewed diſtinct and without Colours by the Eye-Glaſs, or Lens G.

HOWEVER, we find in the Conſtruction of theſe Teleſcopes five Eye-Glaſſes, two of which being placed at leſs than the focal Diſtance of the Object-Glaſs from the End of the Teleſcope, ſeem intended to correct ſome Abberation yet remaining in the Compound Object-Glaſs, in the Manner as explained in the laſt Section; for a bare Amplification of the Field of View does not appear to me to be the ſole Deſign of theſe two Glaſſes extraordinary. The other three Eye-Glaſſes are for the ſame Uſe as in the common Teleſcope.

So that upon the Whole, in this Conſtruction of a Teleſcope there are not leſs than four Glaſſes employed to form the firſt Image of the Object. But this ſeems not to be the natural Reſult of the genuine Theory of Dioptrics, founded on the Doctrine of different refractive Powers and Figures of Glaſſes, and their proper Combination, as I ſhall endeavour to ſhew in a Treatiſe I am now preparing for the Preſs on this Subject, where I ſhall make it appear (at leaſt I think ſo at preſent) that the true Conſtruction of a dioptric Teleſcope is that of a treple Object-Glaſs, or three Lenſes combined together of different Forms and refractive Powers, and alſo three Eye-Glaſſes, as in common Teleſcopes.

INDEED there has been lately publiſhed a large Sort of Opera Glaſs, or Galilean Teleſcope, with a compound Object-Glaſs of three Lenſes, the Figures and refractive Powers of which I have carefully examined, but do not find them conſiſtent with the Theory in any Reſpect. However they perform very well, which plainly ſhews, that an Approximation will oftentimes ſuffice as well as the ſtrict Truth itſelf, eſpecially where the leaſt Advances are made by extremely minute Degrees. This Improvement was ſome Years ago attempted by Mr. Euler abroad, but with what Succeſs in Practice I have not yet learned,

VII. *The Nature of* VISUAL GLASSES *explained, and ſhewn to be an Improvement of* Common Spectacles.

IN the firſt Edition of this Treatiſe I had no Occaſion to make Uſe of Spectacles, and therefore did not ſo thoroughly conſider their Nature, Form, and Uſe as ſince that I have done. It appears to me very wonderful, that an Inſtrument of the moſt common and neceſſary Uſe ſhould have continued lo long of a Form or Make quite contrary to that which the Theory of Optics and the Nature of Viſion require, and yet paſs unobſerved by thoſe who uſe them, and uncenſured by thoſe who have wrote on this Subject; eſpecially if it be conſidered that the erroneous Conſtruction is in itſelf moſt obvious, and in its Effects very prejudicial to the Sight.

THE Fault of the common Spectacles conſiſts in two Particulars, *viz.* 1ſt, The Largeneſs of the Aperture or Diameter of the Glaſſes; and, 2dly, their oblique Poſition to the Axis of the Eye; both which muſt in Time have a very ſenſible Effect upon the Texture of that curious and delicate Organ of Sight, the EYE. But the Harm we receive being not immediately ſenſible, is not conſidered by common People, and therefore not regarded; and when at Length they find their Eyes weakened and impaired, they reckon it as the natural Conſequence of Age, without being apprized how far their Glaſſes have contributed to produce that Effect.

THAT the Area of the Glaſſes in common Spectacles is viſibly larger than is neceſſary, no Body will diſpute, when they conſider how ſmall the Pupil of the Eye is when compared therewith; and that no more Light can be uſeful than that which enters the Pupil. Suppoſe, for Inſtance, the Pupil of the Eye were $\frac{1}{5}$ Part of an Inch in Diameter (which is larger than any I have yet obſerved) and that the Glaſs be one Inch and a half in Diameter, then will the Area of the Glaſs be to that of the Pupil as 225 to 4, which is more than 50 to 1; ſo that there is at leaſt 50 times more Light upon the Eye than is neceſſary for the Purpoſes of Viſion.

If the Aperture of the Glaſs were no longer than that of the Pupil, though it would make the Object appear more diſtinct, there might not in all Caſes be Light enough to ſhew it ſo plainly as might be deſired; neither, as the Glaſſes are placed at a conſiderable Diſtance from the Eye, would there be a ſufficient Field of View. It is neceſſary therefore, that the Aperture of the Glaſſes ſhould be larger than that of the Pupil; and it is well known by Experience, that if the Aperture of the Glaſſes be $\frac{3}{4}$ of an Inch, it will anſwer all Purpoſes of reading, working, *&c.* by them, and in this Caſe but $\frac{1}{4}$ Part of the Light can come upon the Eye as goes to it through a common Spectacle-Glaſs; and therefore by excluding three Parts from four of the ſuperfluous Light, muſt tend greatly to the Safety of the Eye, and procuring diſtinct Viſion of the Object.

Whoever conſiders the great Force which the Action of Light has, and the exquiſitely tender and minute Veſſels in the

Compages of the Eye (exceeding that of any other Part of the Animal Syſtem) will not wonder, that if by ſo great a Quantity of Light which is thrown upon old Eyes by very convex Glaſſes, they ſhould become debilitated, weak, and watery in the Courſe of a few Years. So potent a Cauſe as that of Light by the Conſtancy of its Operation produces very conſiderable Effects, though by very ſlow Degrees. The conſtant Dripping of Water will in a Courſe of Time excavate the hardeſt Stone, though its immediate Effects be not in the leaſt diſcernible, nor any Thing more conſidered than the Action of Light upon the Eye.

THE Difference then between the Viſual Glaſſes is as repreſented in Figure 5, where A B is the open Glaſs, as in common Spectacles, and C D the Glaſs of a reduced Size in the *viſual Form*; the dark Part between that and the Steel Frame E F is a black Zone or Circle of Horn in which the Glaſs is placed, and ſerves at the ſame Time as a Safe-guard and Defence to the Eye againſt extraneous Light.

THE ſecond Thing in which the common Spectacles are moſt egregiouſly faulty, is their being placed direct before the Eye, or both in the ſame Plane, by which Means the Axes of the Glaſs and thoſe of the Eye make a conſiderable Angle with each other; whereas they ought to coincide, or the Glaſſes ſhould be ſo placed before the Eye in two Planes equally inclined, that their Axes may both unite in the Object to which the Eye is directed, and they become one with the Axis of the Eye. To illuſtrate this, let A B be the two *common Spectacle*-Glaſſes, whoſe Axes A C and B D are parallel, and thereby directed to Objects only at an infinite Diſtance, quite contrary to the Deſign of theſe Glaſſes, which is to ſhew a near Object, as ſuppoſe G; then the Glaſſes E, F, are ſo placed in the *new viſual Form* as to have their Axes tending to, and uniting in that Point G; by which Means they become coincident with the Axis of the Eye, and the Rays of Light are regularly and equally refracted to the Pupil. And conſequently the Viſion or Appearance of an Object will by this Means be rendered the moſt natural and eaſy that it poſſibly can be; and indeed the Difference is ſo conſiderable, not only in itſelf, but likewiſe by Experience, that I may venture to prognoſticate, that in a few Years Time, after the Averſions which ariſe from Cuſtom, Intereſt, and Novelty are worn off, the *common Spectacles* will be looked upon as the *Opprobrium* of the Optical Science, and become equally in Contempt and Diſuſe; while the VISUAL GLASSES will approve themſelves the genuine Reſult of Optical Philoſophy, and be uſed at leaſt by all the prudent and thinking Part of Mankind. Thoſe who would ſee a larger Account of this Matter may conſult my *Eſſay on Viſual Glaſſes*, which has paſſed through four Editions.

VII. *Deſcription and Uſes of the* EQUATORIAL TELESCOPE, *or* PORTABLE OBSERVATORY, *by Mr.* James Short, *F. R. S. who firſt adapted a Teleſcope to this Machinery.*

THIS Inſtrument conſiſts of two circular Planes or Plates, marked A A, which are ſupported upon four Pillars; and theſe are again ſupported upon a Croſsfoot, or Pedeſtal, moveable at each End by the four Screws B B B B: The two circular Plates A A are moveable, the one above the other, and are called the horizontal Plates, as repreſenting the Horizon of the Place; and upon the upper one are placed two Spirit-Levels, to render them at all times horizontal: Theſe Levels are fixed at

Right-Angles to one another: This upper Plate is moved by a Handle C, which is called the Horizontal Handle, and is divided into 360°, and has a *Nonius* Index divided into every three Minutes.

ABOVE this horizontal Plate there is a Semicircle D D, divided into twice 90°; which is called the Meridian Semicircle, as repreſenting the Meridian of the Place, and is moved by a Handle E, which is called the Meridian Handle, and has a *Nonius* Index divided into every three Minutes.

ABOVE this Meridian Semicircle is faſtened a circular Plate, upon which are affixed two other circular Plates F F, moveable the one upon the other, and are called the Equatorial Plates; one of them repreſenting the Plane of the Equator, is divided into twice 12 Hours, and theſe are ſubdivided into every 10 Minutes of Time. This Plate is moved by a Handle G, called the Equatorial Handle, and has a *Nonius* Index for ſhewing every Minute.

ABOVE this Equatorial Plate there is a Semicircle H H, which is called the Declination-Semicircle, as repreſenting the Half of a Circle of Declination, or horary Circle, and is divided into twice 90°, being moved by the Handle K, which is called the Declination-Handle. It has alſo a *Nonius* Index for ſubdividing into every three Minutes.

ABOVE this Declination-Semicircle is faſtened a Reflecting Teleſcope L L, of the *Gregorian* Conſtruction, the focal Length of its great Speculum being 18 Inches.

IN order to adjuſt the Inſtrument for Obſervation, the firſt thing to be done, is to make the Horizontal Plates level or horizontal, by means of the two Spirit-Levels, and the four Screws in the Croſs-Pedeſtal. This being done, you move the Meridian Semicircle, by means of the Meridian Handle, ſo as to raiſe the Equatorial Plates to the Elevation of the Equator of the Place; which is equal to the Complement of the Latitude (and which, if not known, may likewiſe be found by this Inſtrument, as ſhall be afterwards ſhewn). And thus the Inſtrument is ready for Obſervation.

To find the Hour of the Day, and Meridian of the Place.

FIRST find, from aſtronomical Tables, the Sun's Declination for the Day, and for that particular Time of the Day; then ſet the Declination-Semicircle to the Declination of the Sun, taking particular Notice whether it is North or South, and ſet the Declination-Semicircle accordingly.

You then turn about the Horizontal Handle, and the Equatorial Handle, both at the ſame time, till you find the Sun preciſely concentrical with the Field of the Teleſcope. If you have a Clock or Watch at Hand, mark that Inſtant of Time; and by looking upon the Equatorial Plate, and *Nonius* Index, you will find the Hour and Minute of the Day, which comparing with the Time ſhewn by the Clock or Watch, ſhews how much either of them differ from the Sun. In this manner you find the Hour of the Day.

Now, in order to find the Meridian of the Place, and conſequently to have a Mark, by which you may always know your Meridian again, you firſt move the Equatorial Plate, by means of the Equatorial Handle, till the Meridian of the Plate or Hourline of 12. is in the Middle of the *Nonius* Index; and then, by turning about the Declination-Handle till the Teleſcope comes down to the Horizon, you obſerve the Place or Point which is then in the Middle of the Field of the Teleſcope; and a ſuppoſed Line drawn from the Centre of this Field to that Point in the Horizon, is your Meridian Line. The beſt Time of the Day for making this Obſervation for finding your Meridian, is about three Hours before Noon, or as much after Noon. The Meridian of the Place may be found by this Method ſo exact, that it will not differ at any time from the true Meridian above 10″ of Time, and if a proper Allowance be made for the Refraction at the time of Obſervation, it may be found much more exact. This Line thus found will be of uſe to ſave Trouble afterwards; and is, indeed, the Foundation of all aſtronomical Obſervations.

To find a Star or Planet in the Day-time, even at Noon-Day.

THE Inſtrument remaining as rectified in the laſt Experiment, you ſet the Declination-Semicircle to the Declination of the Star or Planet you want to ſee; and then you ſet the Equatorial Plate to the Right Aſcenſion of the Star or Planet at that time, and, looking thro' the Teleſcope, you will ſee the Star or Planet; and after you have once got it into the Field, you cannot loſe it: For, as the diurnal Motion of a Star is parallel to the Equator, by your moving the Equatorial Handle ſo as to follow it, you will at any time, while it is above the Horizon, recover it, if it be gone out of the Field.

THE eaſieſt Method for ſeeing a Star or Planet in the Day-time is this: Your Inſtrument being adjuſted as before directed, you bring the Teleſcope down ſo as to look directly at your Meridian Mark; and then you ſet it to the Declination, and Right Aſcenſion, as before-mentioned.

BY this Inſtrument moſt of the Stars of the firſt and ſecond Magnitude have been ſeen even at Mid-day, and the Sun ſhining bright; as alſo *Mercury*, *Venus*, and *Jupiter*: *Saturn* and *Mars* are not ſo eaſy to be ſeen, upon account of the Faintneſs of their Light, except when the Sun is but a few Hours above the Horizon.

AND in the ſame manner in the Night-time, when you can ſee a Star, Planet, or any new Phænomenon, ſuch as a Comet, you may find its Declination and Right Aſcenſion immediately, by turning about the Equatorial Handle, and Declination Handle, till you ſee the Star, Planet, or Phænomenon; and then, looking upon the Equatorial Plate, you find its Right Aſcenſion in time; and you find, upon the Declination-Semicircle, its Declination in Degrees and Minutes.

IN order to have the other Uſes of this Inſtrument, you muſt make the Equatorial Plates become parallel to the Horizontal Plates; and then this Inſtrument becomes an *Equal Altitude Inſtrument*, a *Tranſit Inſtrument*, a *Theodolite*, a *Quadrant*, an *Azimuth Inſtrument*, and a *Level*. The manner of applying it to theſe different Purpoſes is too obvious to need any Explanation.

As there is alſo a Box with a magnetic Needle faſtened in the lower Plate of this Inſtrument, by it you may adjuſt the Inſtrument nearly in the Meridian; and by it likewiſe you may find the Variation of the Needle: If you ſet the Horizontal Meridian, and the Equatorial Meridian, in the Middle of their *Nonius* Indexes, and direct your Teleſcope to your Meridian Mark, you obſerve how many Degrees from the Meridian of the Box the Needle points at; and this Diſtance or Difference is the Variation of the Needle.

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FINIS.

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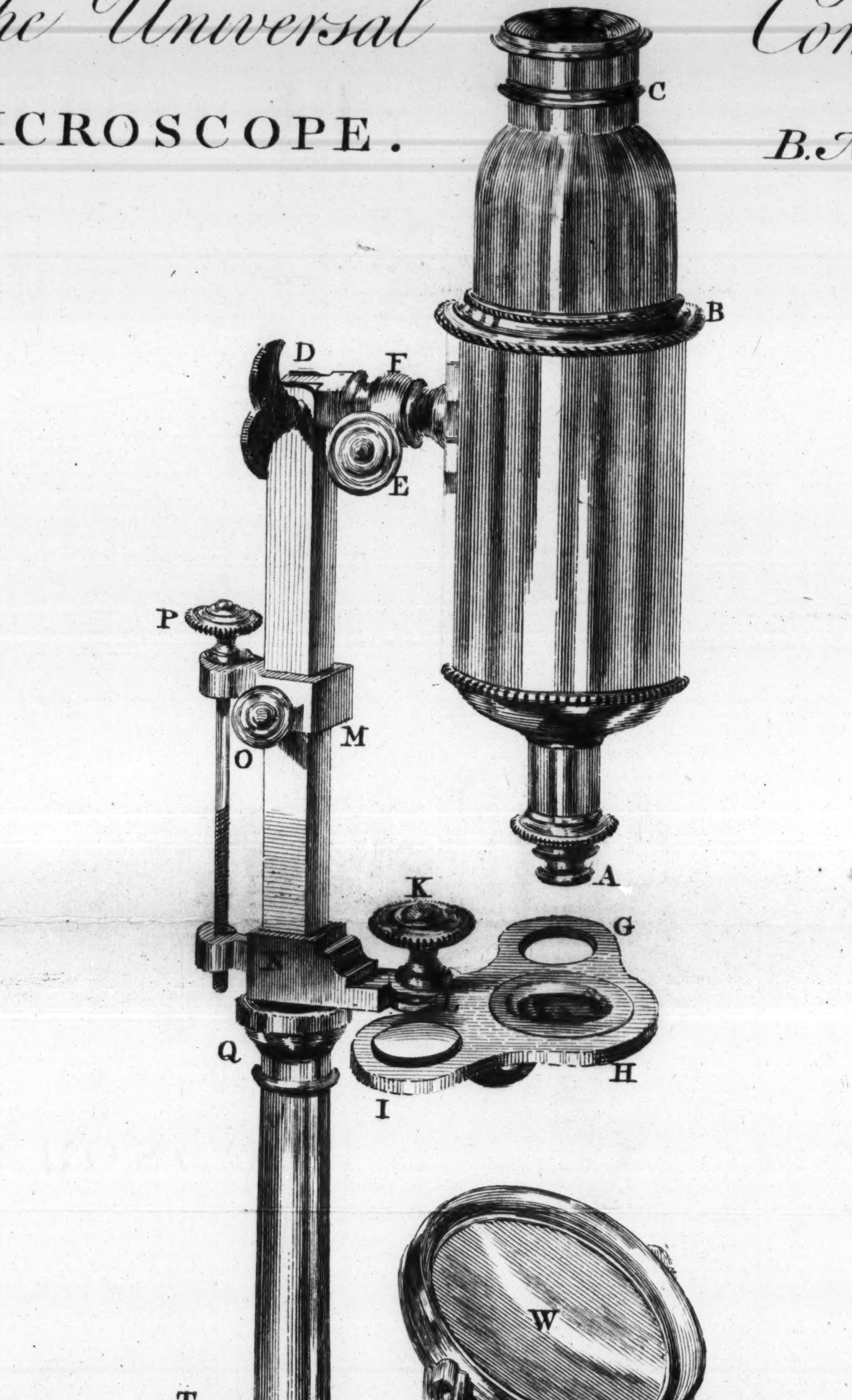
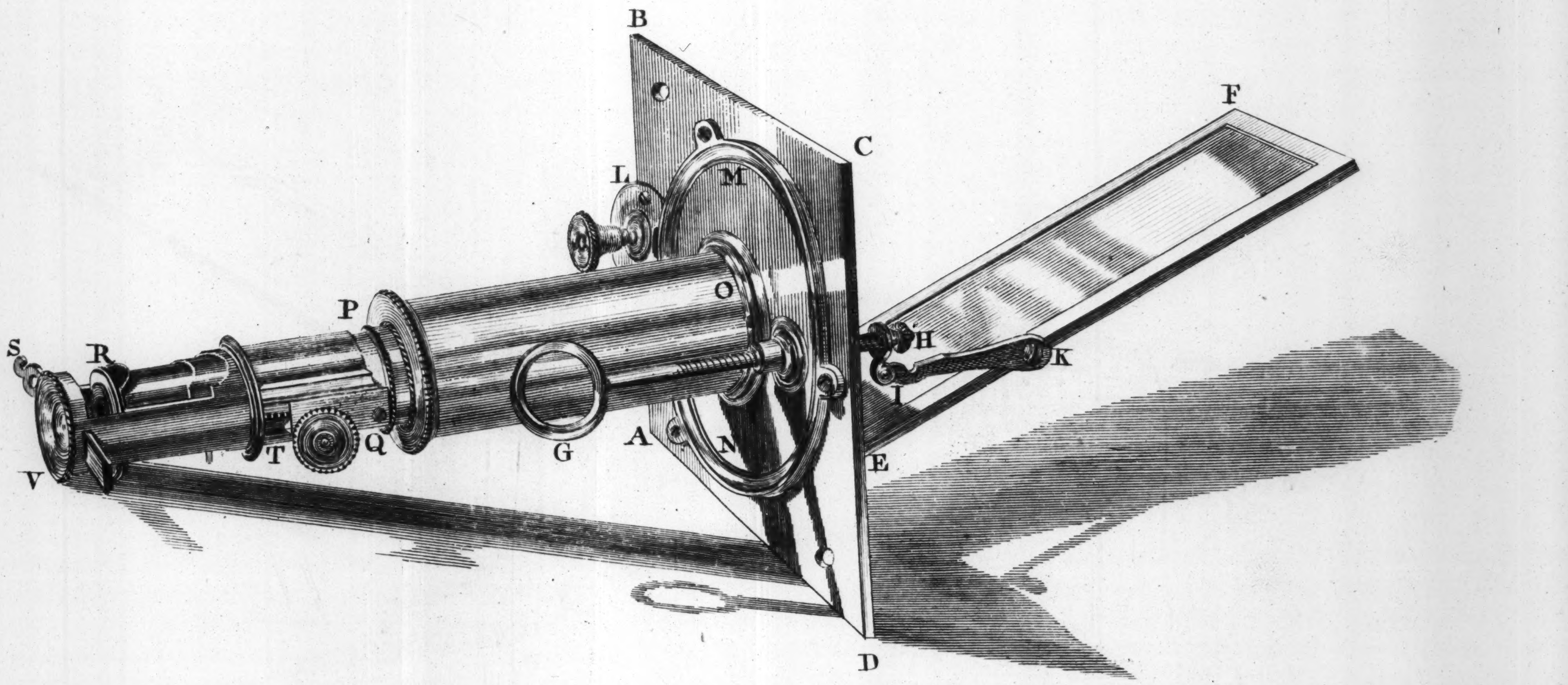
The Universal Compound MICROSCOPE.

B. MARTIN, Inv.t



Appendix II. *Plate* II.

The New, SOLAR MICROSCOPE.



Appendix II. Plate III.

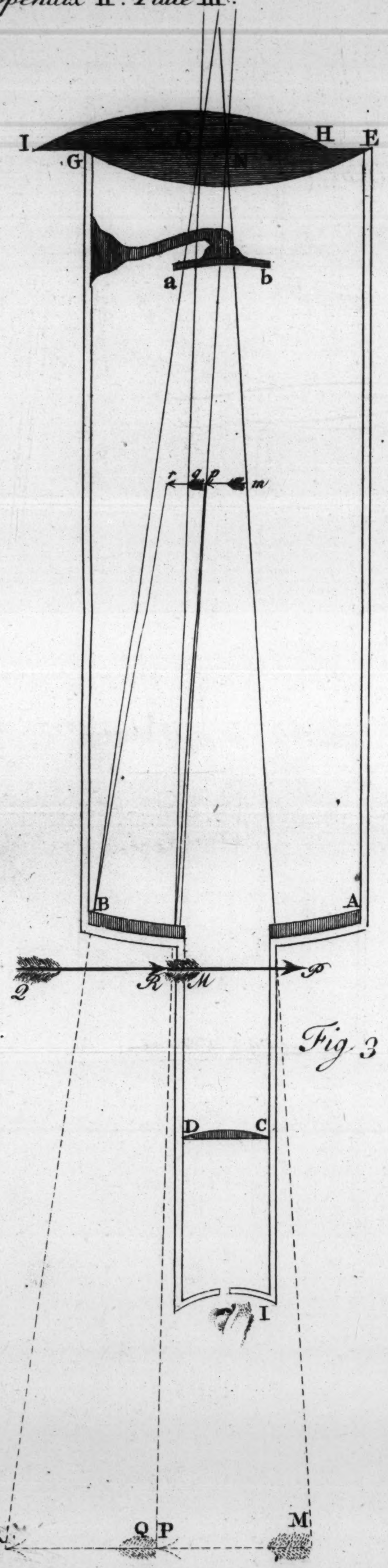


Fig. 3.

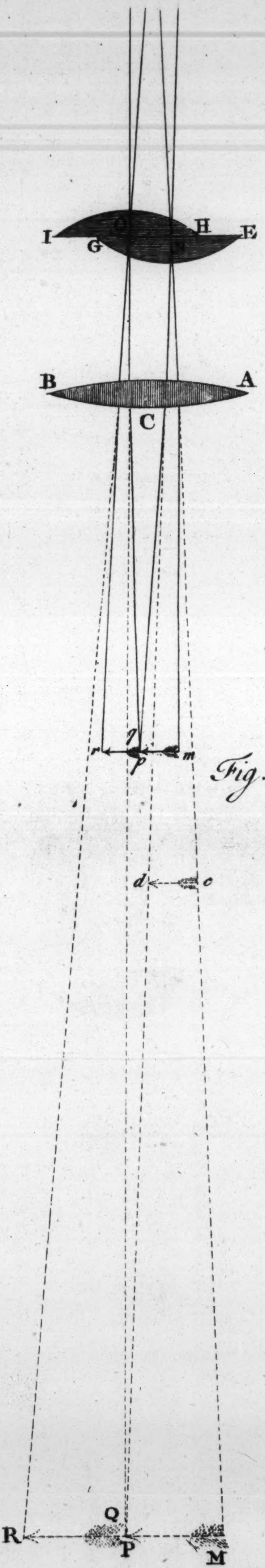


Fig. 2.

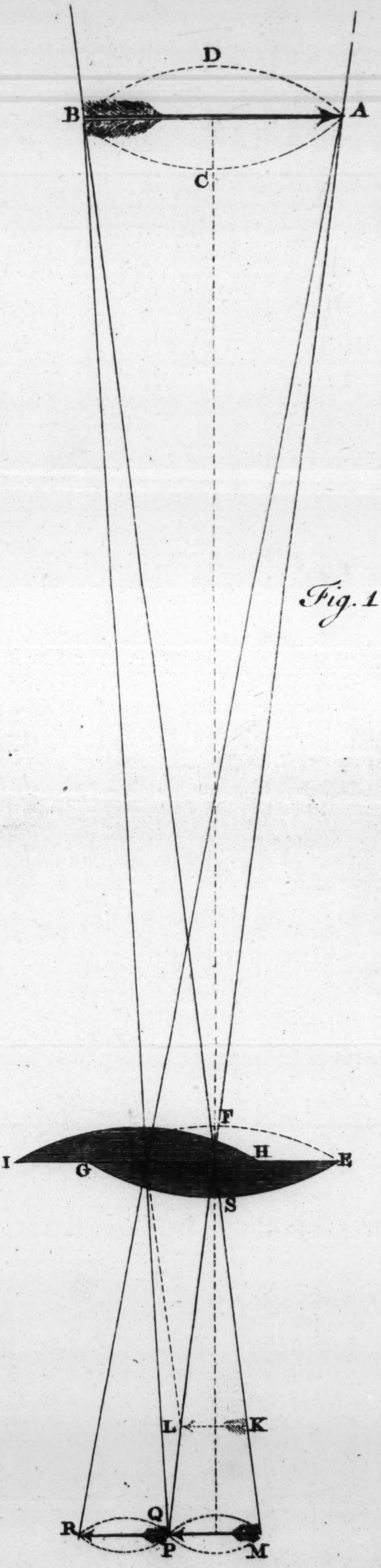
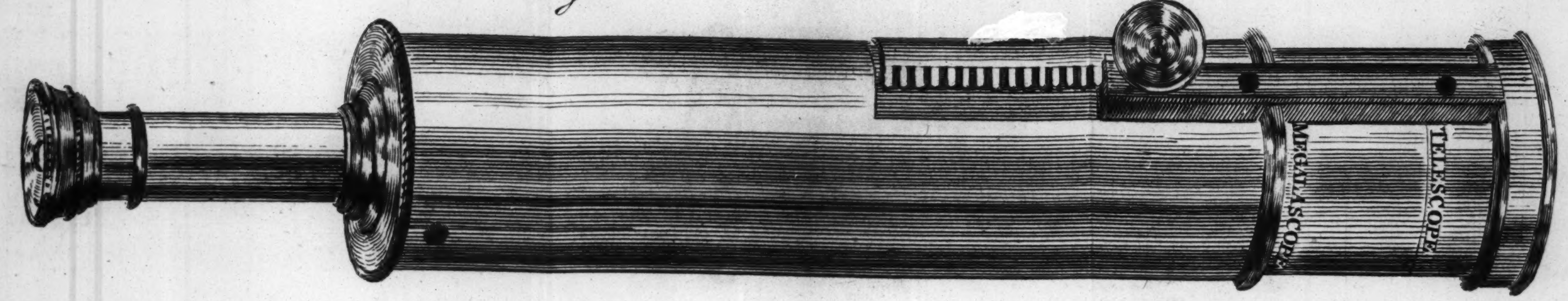


Fig. 1.

Appendix II. *Plate* IV.

Fig. 1.



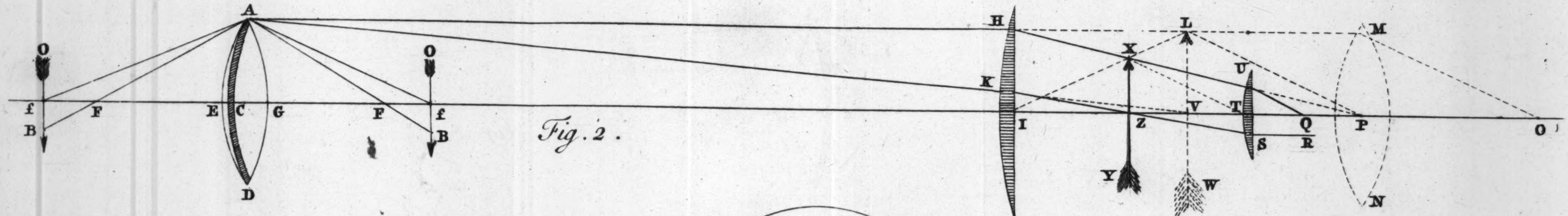


Fig. 2.

Fig. 3.

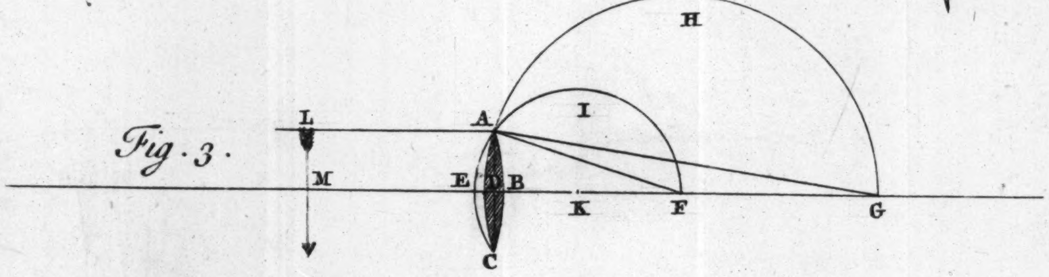
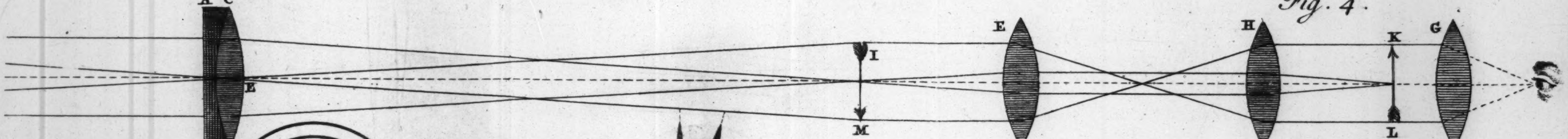


Fig. 4.



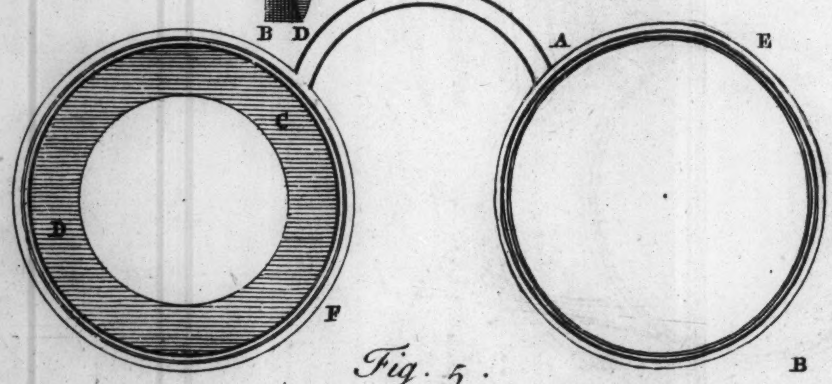


Fig. 5.

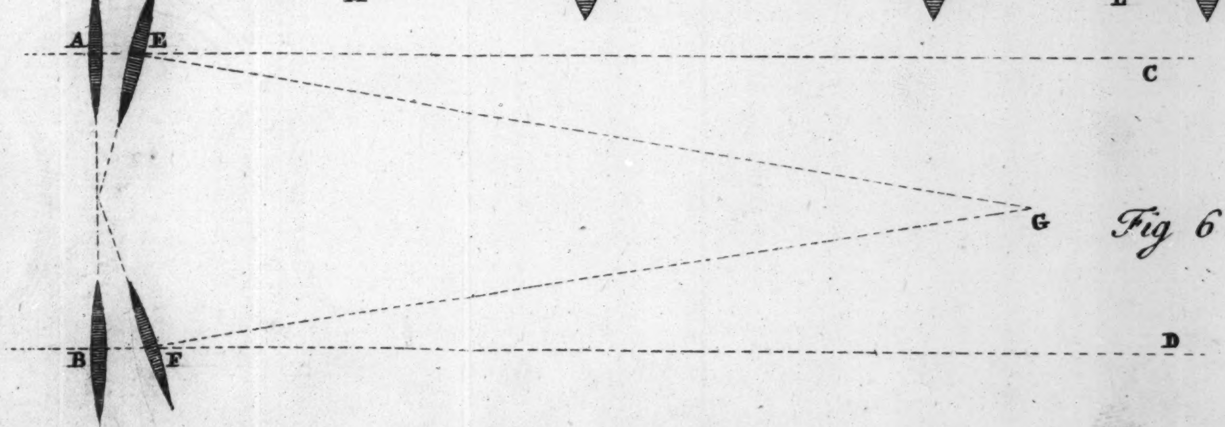


Fig. 6.

The EQUATORIAL TELESCOPE